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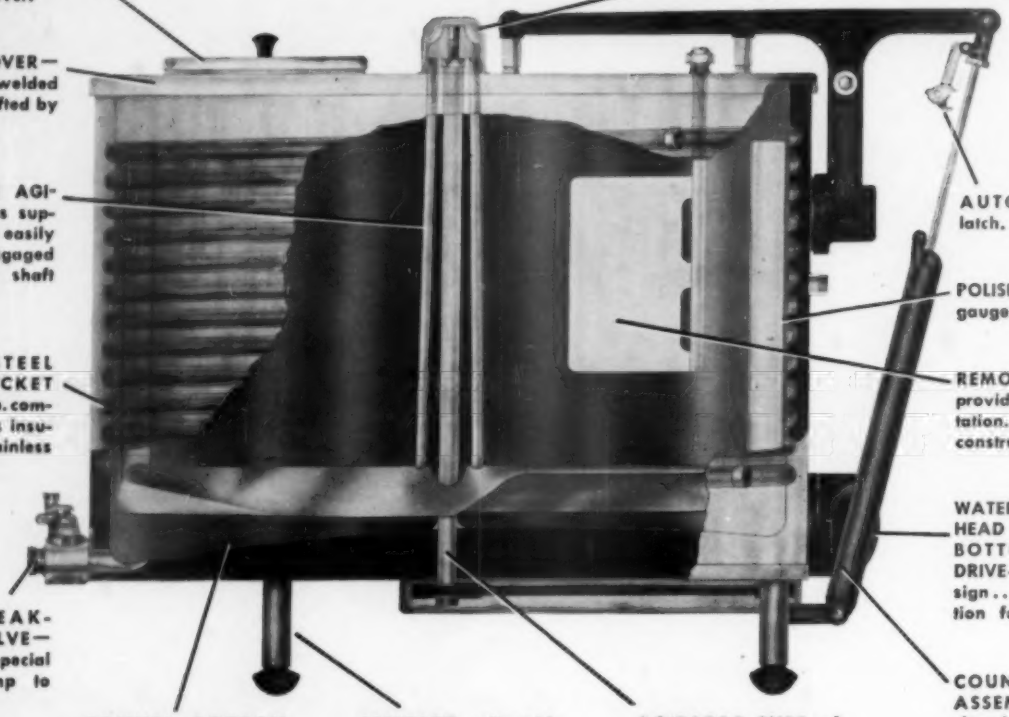

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# Objective Measurement in Quality Control of Frozen Foods[a]

J. L. HEID AND B. W. NIELSEN
*Golden Citrus Juices, Inc., Fullerton, California*

(Manuscript received May 21, 1951)

A REVIEW

**The objective testing of frozen fruit products is receiving attention to increase accuracy, precision, and value in terms predicting acceptability of products. Objective tests for physical and chemical characteristics which are related to the appearance, texture, taste, flavor, and food value of frozen fruit products are valuable indices to acceptability because they are easily applied and the results are more reproducible than those obtained by sensory tests. Such tests are discussed with special regard to their application in frozen citrus products.**

Although purchasers expect considerable variation in "fresh" fruit and vegetables, they demand excellent quality and uniformity in packaged frozen foods.

It is the responsibility of quality control technologists to select suitable raw materials and control processing operations to produce acceptable and uniform packaged foods. They are fundamentally concerned with the development and improvement of control procedures, tests, and standards. They know that seasonal, regional, climatic, varietal, and soil factors result in constant variations in raw materials and only by maintaining detailed records and graphs of changes in composition and characteristics can they compensate advantageously and pack uniform products.

The acceptability of frozen foods depends upon their appeal to the four senses: sight, touch, taste, and smell. (1) The appearance of packages and of contents is the first factor observed by consumers. Color, size, shape, gloss, surface texture, degree of wholeness, and the clarity of juices, syrups, or brines are noted through the sense of sight. (2) The sense of touch informs us whether a product is hard, soft, tough, or tender, and whether the sensation on surfaces in the mouth and throat is pleasant or otherwise. (3) The sense of taste measures sweetness, sourness, bitterness, saltiness, hotness, and perhaps other sensations not easily described. (4) The sense of smell gauges the aroma and in general identifies the type, variety, and condition of a food. The scent of raw, pasteurized, and fermented juice products, the degree of cooking, freshness or staleness, and similar factors are indexed according to reactions of our sense of smell.

Only hearing is omitted from the jury of senses which must be pleased to secure the acceptance of packaged frozen foods; and radio commercials strive to enlist even that sense in stimulating food acceptance.

It might appear simple for the technologist to examine and taste samples and classify them as good or bad, suitable or unsuitable. Actually, processors do depend on "subjective" or "sensory" tests to a considerable degree and with considerable success. There is a great variation in the ability of individuals to render consistent evaluations by sensory tests, but in a commercial organization, able and responsible testers can usually be selected by trial; results can be checked and sources of discrepancy can be eliminated. However, there are inherent restrictions in the application of sensory tests. They do not yield data which can be recorded, tabulated, and graphed for comparison and study and for reference in adjusting formulae and processes. Even with skilled testers, ability to distinguish difference may be blunted when multiple samples are examined.

Subjective tests are not well suited for use by State or Federal Regulatory testers because results depend upon the ability of individuals to differentiate consistently and this varies with every individual tester and with each type of food. Only 10% of tested individuals were able to produce consistent evaluations of variations in citrus juices. The results of subjective tests are influenced not only by the acuity of taste perception for each specific food but also by the taster's physical and mental condition and by transient or permanent biases and idiosyncrasies. Consequently, food technologists are confronted with the necessity of developing objective tests which will be useful in estimating the acceptability of frozen foods. The value of any physical or chemical method is checked by measuring its ability to furnish information useful in predicting the reaction of a selected and trained taste panel.

Objective tests may be differentiated from subjective tests or sensory tests on a basis that they can be substantially and dependably duplicated by trained technicians at different times and places. Actually there is not always a sharp line between subjective and objective tests. Improved techniques and devices tend to move tests from classification as subjective into classification as objective.

In this discussion it is proposed to review some objective tests which are used in evaluating frozen fruit products and, more specifically, frozen citrus fruit products. The net contents of packages may be measured by weight or volume or by a combination. Not infrequently it is easier to measure the density and weight of a liquid and compute the volume than to accurately measure the volume of liquid in each package. When fruit packs such as grapefruit sections, are packed in a syrup or brine, the drained weight as well as the net weight may furnish an index to the maturity of the fruit, how the package has been filled and whether the freezing process has resulted in objectionable modification of cell structures.

Formerly greater emphasis was sometimes placed upon appearance than upon flavor or eating quality. Standards with this inclination were referred to as "Augen" standards. Fully ripe fruit, frozen in syrup, is usually softer than less mature fruit. Sliced, ripe Elberta peaches may appear "ragged" and the syrup may be cloudy. Packers were tempted to select fruit harvested at a stage when firm pieces and clear syrups could be assured. When this was at the expense of flavor, consumers rejected products. "Home style"

[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 20, 1951.

packs of peaches and other foods were considered superior by consumers with the result that standards have tended to become more concerned with flavor and texture than exclusively with eye appeal.

Most frozen fruit standards include a requirement covering color. Reasonably satisfactory instruments are available for measuring color by reflected or transmitted light. The Munsell system using disc standards, is not entirely objective but has been widely used. Spectrophotometric and photoelectric methods for measuring color reduces subjective factors in color measurement. Actually, there is normally so much regional, seasonal, and varietal variation in color of citrus fruits and juices that precise measurements are not sufficiently significant to warrant the time and expense required to make them. Color defects may be an index to improper maturity, processing, or variety. In Processing and Marketing Administration (P.M.A.) Standards *(7)*, color is usually allocated a weight of 20 points, with 17 to 20 for very good, 14 to 16 for good, and 0 to 13 when an off-color exists.

"Absence of defects" in P.M.A. Standards *(7)*, is rated at 40% and refers to the degree of freedom from flaws such as seeds, portion of skin or interlocular membranes, etc., in citrus fruit and juice products. In the early days of the juice industry when juice was extracted in grinders or hand reaming, considerable emphasis was placed upon the quantity of suspended pulp which could be separated by centrifuging the juice. Excessive pulp may indicate high pressure during reaming or screening of the juice resulting in the incorporation of undesirable quantities of peel extractives in the juice. Actually, flavor, oil content, enzyme activity, bitterness, and other characteristics of the juice offer a sounder clue to improper methods of extraction or straining than the quantity of suspended pulp which may or may not be related to the acceptability of the juice. Frozen, concentrated juice products are intentionally strained through coarse strainers so that the reconstituted juice carries large quantities of juice sacs and other suspended "juice" solids which consumers prefer. Large seeds, membrane, or peel particles are defects and are restricted.

## OBJECTIVE TESTS

Objective tests applied to the composition of citrus juice products include total soluble solids, citric acid, and volatile water-immiscible oils. Soluble solids are not ordinarily determined directly but are estimated by measuring either the refractive index or the density. The common index of comparison is in terms of degrees "Brix." "Brix" expresses density calibrated directly in terms of percentage of sugar by weight in a pure sucrose solution *(2)*.

Citrus juices contain other soluble and insoluble factors such as ash constituents, citric acid, and nitrogen compounds. The Brix scale does not exactly coincide with the percentage of soluble solids, but is the basis of State and Federal Standards because it can be easily measured by means of a spindle (hydrometer) or by weighing a standard volume of deaerated juice.

The refractive indices of pure sucrose solutions of varied concentrations are known and refractometers are calibrated directly in percentage of sucrose in pure solution. For citrus juices a correction is applied, based upon the citric acid content, to bring the Brix, measured by refraction or by density, into close agreement *(6)*.

The viscosity of concentrated juice is not commonly measured but is of considerable importance in designing equipment for handling the juice, and is another item for quality control. Citric acid accounts for substantially all the acid present in unfermented citrus juices and is measured by titration with standard sodium hydroxide solution. The ratio of Brix to acid is an index to the sweetness of orange, tangerine, and grapefruit juices and is also related to the maturity of the fruit, so that the ratio can be used in maturity standards for a specific variety in a specific area of production.

Another objective test of value in estimating acceptability and keeping quality of citrus juices is the determination of volatile, immiscible oil by steam distillation in a modified Clevenger apparatus. Two liters of juice are refluxed for an hour and the volume of condensed oil is measured in a calibrated capillary. Because of the relation of oil content to control of processing operations more rapid methods are sought. Burdick and Allen *(4)* have described a method for estimating the oil content of citrus juices by mixing 100 ml. juice with 25 ml. of acetone, distilling for 7 minutes and measuring the turbidity of the condensate.

The determination of ascorbic acid in frozen citrus and other fruit products is of primary importance for a number of reasons. It is an index to the condition and maturity of raw materials, losses during processing, and indicates the degree of success of processing methods. Actually, no measurable loss in ascorbic acid should occur in processing any citrus juice product in frozen form. Excessive exposure to unfavorable metals such as copper, or to oxygen in the air, or undue delay in preparation may cause measurable losses. Titration with 2,6 dichlorophenolindophenol in a solution buffered with phosphoric acid is a yardstick to food value, condition of raw products, and success of the process. Skilled technicians are able to obtain accurate results although the end-point in highly colored juices is not easy to observe *(1)*.

Rate of flocculation or settling in citrus juices is measured to ensure against consumer complaints. Excessive pectin and pectic enzymes may cause rapid flocculation and sedimentation in orange juice products which have not been heated sufficiently to inactivate enzymes. Variety and maturity of fruit affect the flocculation rate, but the amount of pressure and grinding in juice extractors and strainers is the largest single factor which is involved. Tests for specific enzymes may be made but in ordinary control procedures on citrus juices these are less commonly applied than observation of the amount of settling occurring in a portion of juice standing for a prescribed period at room temperature in a glass cylinder.

In citrus and other "cloudy" fruit juices, turbidity is usually related to acceptability. Kertesz *(5)* described a simple device for estimating turbidity. Because of the high cost of nephelometers and photoelectric colorimeters, he suggested the use of a wedge-shaped cell with a calibrated scale which is filled with the juice. By observing the thickest layer at which scale calibrations could be seen under standard light conditions, it is possible to compare turbidity with a satisfactory degree of accuracy. The result, expressed as Turbidity Number, is the maximum thickness in centimeters of the layer of juice through which the scale graduation can be still seen.

Consumers have shown a preference for frozen citrus juice products containing suspended pulpy material, principally juice sacs. This pulp is usually measured by straining a prescribed volume of juice through a tea strainer with 0.04-inch openings in the mesh. After the pulp is rinsed and shaken, the amount of pulp is estimated by weighing. The character of pulp is observed after dilution with water which makes it easier to detect the presence of undesirable seed particles, interlocular membrane or peel fragments.

Hydrogen ion determination (pH) measurement is routine at every stage of frozen citrus products manufacture. The measurement of ash constituents by A.O.A.C. *(1)* methods is a valuable control procedure for evaluation of quality and uniformity as well as source of raw materials. These determinations may also furnish clues to substitution of less costly ingredients. Nitrogen determinations may be used for similar purposes.

Resistance to deformation, penetration, sheer, and leakage is often useful in evaluating quality in frozen fruit products. Tenderometers, succulometers, and penetrometers permit mathematical gradings of these factors. Interesting developments are occurring in improving instruments for these measurements.

Microbiological examination of frozen citrus products is of primary importance as a check on success in cleaning fruit and equipment and avoidance of contamination during processing. A complete check upon plant sanitation is essential to the production of uniform high-quality frozen citrus products which are never heated in a way which would kill spoilage organisms. Microbiological test procedures include testing for coliforms using a modified Vaughn-Levine boric acid medium *(3)*. Plate counts on various media in petri dishes are used for estimating total viable organisms or special groups. Commonly used media include orange serum, Lindegren's agar, and triptone glucose extract agar.

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# Investigation of Salmonella Content of Powdered Whole Egg With Not More Than Two Percent Moisture Content. IV. Bactericidal Action of the Preheater on Salmonella in Liquid Whole Egg


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(Manuscript received May 3, 1951)


**The use of the preheater for minimizing the potential health hazard due to Salmonella in commercially processed spray-dried, low-moisture, whole egg powder is clearly demonstrated in this study.**


Commercial liquid whole egg is generally known to have high viable bacterial loads and has been considered a potential vehicle for wide dissemination of pathogenic bacteria such as *Salmonella*. In the manufacture of spray-dried whole egg powder, the presence of these bacteria in the product is undesirable. Liquid whole egg produced from chicken eggs under laboratory conditions has rarely been found to be contaminated with *Salmonella*, according to Cantor and McFarlane *(2)* and Chase and Wright *(3)*. The latter workers examined a large number of eggs and isolated only *S. pullorum*, a species native to fowls. Solowey, Spaulding and Goresline *(8)* have expressed the opinion that the external egg shell surface is an important source of contamination with *Salmonella*, unknowingly introduced into liquid whole egg by egg-breaking personnel.

[a] This work was done while the author served as Captain, Veterinary Corps, U. S. Army, at the Seventh Service Command Medical Laboratory, Fort Omaha, Omaha, Nebraska. The views or conclusions contained in this report are those of the author. They are not to be construed as necessarily reflecting the views or indorsement of the Department of Defense.

At the time of this study the specification *(5)* for procurement of low-moisture, whole egg powder for the Armed Forces included a requirement for the use of a preheater in the processing of whole egg powder. While the preheater was primarily intended for lowering the moisture content in the egg product, it also had the important function of bacterial destruction. The author *(6, 7)* has presented strong evidence which associates the preheater with significant reduction of the incidence of *Salmonella* in spray-dried, low-moisture, whole egg powder. Pasteurization of liquid whole egg is an effective means of destroying *Salmonella* in this product, according to Winter, et al. *(10, 11)*. Solowey, Sutton, and Calesnick *(9)* reported a heat-resistance study of 24 *Salmonella* types isolated from egg powder; they express the opinion that flash pasteurization at 60° C. of liquid whole egg would markedly reduce the number of *Salmonella* organisms in the egg powder.

This study is a detailed account of an earlier work by the author on the function of the preheater in destroying *Salmonella* in heated commercial liquid whole egg which minimizes the potential health hazard from these bacteria in the processed egg powder. The data include information on total viable bacterial loads of the liquid as well as the spray-dried whole egg.

Between February, 1945 and July, 1945 a uniform system of Veterinary Corps Inspection Service afforded

an opportunity to examine microbiologically a random series of egg pulp samples procured for Army "Backlog" [b] [de Tienne, *(4)*]. The incidence of *Salmonella* is noted in this product.

Limited observations are recorded on the occurrence of *Salmonella* in high-moisture (5%) whole egg powder procured under Army Veterinary inspection during 1945.

## EXPERIMENTAL PROCEDURE

Processing technology of three commercial egg dehydrating establishments were studied extensively. Six daily production runs of whole egg powder, including the raw, flash heated [60.5-61.8° C. (141-143° F.)] and pasteurized liquid egg were examined qualitatively for the presence of *Salmonella* organisms. Defrosted whole egg and fresh-broken out whole egg (from spring-produced current receipts) served as the source materials for the experiments herein reported. Liquid and spray-dried whole egg were collected at hourly intervals during full day production runs. Experiments conducted in plant A are noteworthy because two Rogers-type spray driers were being operated in parallel. The preheater to one of the driers was shut down. It was thus possible to dry one source of defrosted whole eggs under two conditions simultaneously, namely, with and without the processing aid of the preheater. In plants B and C egg processing operations were carried out with and without assistance of the preheater on each of two consecutive days. Defrosted whole egg was the source material for the commercial production run in plant B, while fresh liquid whole egg from spring-produced current receipts were employed in plant C.

The procedure used for isolation and identification of *Salmonella* organisms has already been reported by the author *(6, 7)*. Standard plate counts of viable bacteria were determined as previously described *(7)*.

## RESULTS

During the microbiological examination of the 1945 frozen egg "Backlog," 199 samples of egg pulp were examined for the presence of *Salmonella* organisms. An incidence of 30.7% was found. Of 61 isolations, 60 cultures were *S. pullorum* and one culture was *S. oranienburg*.

Sixty-three lots of high-moisture whole egg powder (containing about 5% moisture) showed an incidence of *Salmonella* organisms of 9.5%. Six cultures of *Salmonella* were identified and included *S. typhi-murium*, *S. montevideo*, *S. paratyphi B*, *S. cerro*, and two cultures of *S. oranienburg*.

Under conventional operating conditions in plants A and B using Rogers-type spray driers, the preheater is definitely effective in reducing the *Salmonella* incidence in spray-dried whole egg powder. Even with apparently heavy contamination of the defrosted raw whole egg liquid, the preheater was the site of *Salmonella* destruction. Results are summarized in Tables 1, 2, and 4. The first of two experiments in plant C, using a Douthitt-type drier, were conducted during the season of spring egg receipts. Here *S. pullorum* was recovered from low-moisture whole egg powder processed without the assistance of the preheater (Table 5). On the second day of the test, the liquid whole egg was preheated, and in addition, held for 6 minutes at 60.5-61.8° C. (141-143° F.). No *Salmonella* were found in fourteen samples of egg powder obtained from spray-drying the pasteurized liquid egg.

The survey of spring egg receipts and observations on the unheated whole egg liquid used for spray-drying during the same spring season (Tables 3 and 5) revealed *S. pullorum* as the principal contaminant of the liquid egg mix. On the other hand, during November and December, 1944, unheated defrosted liquid eggs in plants A and B were heavily contaminated with a variety of *Salmonella* types other than and including *S. pullorum*.

Based on standard plate counts of viable bacteria in egg during two consecutive production runs at plant C, commercial practices of preheating and short-time pasteurization of liquid whole egg made the isolation of

[b] "Backlog," a term used by de Tienne, refers to high quality frozen eggs procured for production of egg powder for military needs. She has presented evidence that effective sanitary measures during production and processing of frozen whole eggs will result in relatively low viable bacterial counts of manufactured egg powder.

TABLE 1

Survival of *Salmonella* in commercial spray-dried, low-moisture, whole egg powder. Plant A, Twin Rogers-Type Driers [c]

| Liquid whole egg, unheated | | | Low-moisture whole egg powder processed without aid of preheater | | | Low-moisture whole egg powder processed with aid of preheater (flash to 140–141° F.) | | |
|---|---|---|---|---|---|---|---|---|
| Hour of operation | SPC [c] per gram | *Salmonella* isolated | Hour of operation | SPC [c] per gram | *Salmonella* isolated | Hour of operation | SPC [c] per gram | *Salmonella* isolated |
| 1 | 880,000 | *S. oranienburg* | 1 | 105,000 | ..... | 1 | 8,600 | *S. tennessee* |
| 2 | 880,000 | .....[d] | 2 | 85,000 | ..... | 2 | 10,600 | ..... |
| 3 | 640,000 | ..... | 3 | 152,000 | *S. oranienburg* | 3 | 11,700 | ..... |
| Liquid whole egg, preheated (flash to 140-141° F.) | | | 4 | 9,800 | *S. oranienburg* | 4 | 10,400 | ..... |
| | | | 5 | 12,000 | ..... | 5 | 4,000 | ..... |
| | | | 6 | 14,800 | ..... | 6 | 4,400 | ..... |
| 1 | 660,000 | ..... | 7 | 15,300 | *S. oranienburg* | 7 | 5,200 | ..... |
| 2 | 30,000 | ..... | 8 | 11,900 | ..... | 8 | 4,000 | ..... |
| 3 | 30,000 | ..... | 9 | 13,900 | ..... | 9 | 4,000 | ..... |
| | | | 10 | 8,400 | ..... | 10 | 7,600 | ..... |
| | | | 11 | 9,900 | ..... | 11 | 11,800 | ..... |
| | | | 12 | 11,000 | ..... | 12 | 21,000 | ..... |
| | | | 13 | 4,700 | ..... | 13 | 22,800 | ..... |
| | | | 14 | 11,300 | ..... | 14 | 74,000 | ..... |
| | | | 15 | 16,400 | ..... | 15 | 24,500 | ..... |
| | | | 16 | 12,500 | ..... | 16 | 21,000 | ..... |
| | | | 17 | 37,000 | ..... | 17 | 66,000 | ..... |
| | | | 18 | 44,000 | ..... | 18 | 78,000 | ..... |
| | | | 19 | 10,200 | ..... | 19 | 70,000 | ..... |
| | | | 20 | 7,600 | ..... | 20 | 50,000 | ..... |

[c] SPC is standard plate count.
[d] *Salmonella* organisms not detected.
[e] Driers operating simultaneously, November 15, 1944.

TABLE 2

Survival of *Salmonella* in commercial spray-dried, low-moisture, whole egg powder. Plant A, Twin Rogers-Type Driers [f]

| Liquid whole egg, unheated | | | Low-moisture whole egg powder processed without aid of preheater | | | Low-moisture whole egg powder processed with aid of preheater (flash to 140–141° F.) | | |
|---|---|---|---|---|---|---|---|---|
| Hour of operation | SPC [g] per gram | *Salmonella* isolated | Hour of operation | SPC [g] per gram | *Salmonella* isolated | Hour of operation | SPC [g] per gram | *Salmonella* isolated |
| 1 | 44,000 | *S. tennessee* | 1 | 30,400 | *S. pullorum* | 1 | 40,000 | ..... |
| | | *S. oranienburg* | 2 | 12,000 | ..... | 2 | 32,000 | ..... |
| 2 | 104,000 | *S. pullorum* | 3 | 36,000 | ..... | 3 | 10,400 | ..... |
| | | *S. tennessee* | 4 | 29,600 | ..... | 4 | 44,000 | ..... |
| | | *S. oranienburg* | 5 | 45,000 | ..... | 5 | 67,000 | ..... |
| 5 | 156,000 | *S. tennessee* | 6 | 20,800 | ..... | 6 | 40,000 | ..... |
| 6 | 60,000 | ..... | 7 | 25,000 | ..... | 7 | 54,000 | ..... |
| 21 | 1,320,000 | ..... | 8 | 20,800 | *S. pullorum* | 8 | 76,000 | ..... |
| Liquid whole egg, preheated (flash to 140-141° F.) | | | 9 | 80,000 | ..... | 9 | ..... | ..... |
| | | | 10 | 33,000 | *S. pullorum* | 10 | 32,400 | ..... |
| 1 | 8,000 | ..... | 11 | 30,400 | ..... | 11 | 31,200 | ..... |
| 2 | 20,000 | ..... | 12 | 17,600 | ..... | 12 | 40,000 | ..... |
| 6 | 12,000 | ..... | 13 | 72,000 | *S. pullorum* | 13 | 104,000 | ..... |
| 21 | 410,000 | ..... | 14 | 72,000 | ..... | 14 | 70,000 | ..... |
| | | | 15 | 196,000 | *S. pullorum* | 15 | 100,000 | ..... |
| | | | 16 | 142,000 | *S. pullorum* | 16 | 80,000 | ..... |
| | | | 17 | 410,000 | *S. pullorum* | 17 | 112,000 | ..... |
| | | | 18 | 160,000 | *S. pullorum* | 18 | 120,000 | ..... |
| | | | 19 | 141,000 | *S. pullorum* | 19 | 200,000 | ..... |
| | | | 20 | 260,000 | *S. pullorum* | 20 | 182,000 | ..... |
| | | | 21 | 1,040,000 | *S. pullorum* | 21 | 600,000 | ..... |

[f] Driers operating simultaneously, November 25, 1944.
[g] Standard plate count.

TABLE 3

Effect of the preheater on the survival of *Salmonella* organisms found naturally in commercial liquid whole egg. Plant A [h]

| | Hour of operation | Temperature of egg pulp | SPC [i] per gram | *Salmonella* isolated |
|---|---|---|---|---|
| | | ° F. | | |
| Liquid whole egg, unheated | 1 | ..... | 172,000 | ..... |
| | 4 | ..... | 89,000 | *S. pullorum* |
| | 8 | ..... | 95,000 | *S. pullorum* |
| | 12 | ..... | 116,000 | ..... |
| | 16 | ..... | 288,000 | ..... |
| Liquid whole egg, preheated (flash) | 1 | 140 | 5,806 | ..... |
| | 2 | 141 | 4,700 | ..... |
| | 3 | 140 | 7,900 | ..... |
| | 4 | 140 | <3,000 | ..... |
| | 5 | 141 | 4,200 | ..... |
| | 6 | 140 | 6,600 | ..... |
| | 7 | 140 | 12,000 | ..... |
| | 8 | 140 | 15,000 | ..... |
| | 9 | ..... | 62,000 | ..... |
| | 10 | 140 | 18,000 | ..... |
| | 11 | 141 | 18,000 | ..... |
| | 12 | 140 | 45,000 | ..... |
| | 13 | 140 | 22,000 | ..... |
| | 14 | 140 | 15,000 | ..... |
| | 15 | 140 | 12,000 | ..... |
| | 16 | 140 | 80,000 | ..... |
| | 17 | 140 | 44,000 | ..... |
| | 18 | 140 | 47,000 | ..... |
| | 19 | 140 | 53,000 | ..... |

[h] February 15, 1945.
[i] Standard plate count.

TABLE 4

Survival of *Salmonella* in commercial spray-dried, low-moisture, whole egg powder. Plant B, Rogers-Type Drier.

| Liquid whole egg, unheated [j] | | | Liquid whole egg, unheated [k] | | |
|---|---|---|---|---|---|
| Hour of operation | SPC [l] per gram | *Salmonella* isolated | Hour of operation | SPC [l] per gram | *Salmonella* isolated |
| 1 | 53,000 | *S. oranienburg* | 1 | 86,000 | *S. pullorum* |
| 4 | 63,000 | *S. oranienburg* | 4 | 55,000 | *S. pullorum* |
| 8 | 63,000 | *S. oranienburg* | 8 | 30,000 | ..... |
| 12 | 52,000 | *S. oranienburg* | 12 | <30,000 | *S. oranienburg* |
| 16 | 68,000 | *S. oranienburg* | 16 | <30,000 | *S. oranienburg* |
| Low-moisture whole egg powder processed without aid of preheater [j] | | | Liquid whole egg, preheated (flash to 141-143° F.) [k] | | |
| | | | 1 | <30,000 | ..... |
| 4 | 27,300 | *S. pullorum* | 4 | <30,000 | ..... |
| 5 | 20,400 | *S. oranienburg* | 8 | <30,000 | ..... |
| 6 | 16,600 | *S. pullorum* | 12 | <30,000 | ..... |
| 7 | 20,000 | ..... | 16 | <30,000 | ..... |
| 8 | 12,000 | *S. pullorum* | Low-moisture whole egg powder processed with aid of preheater (flash to 141-143° F.) [k] | | |
| 9 | 14,000 | ..... | | | |
| 10 | 17,900 | ..... | 2 | 7,000 | ..... |
| 11 | 14,600 | *S. pullorum* | 3 | 9,200 | ..... |
| | | *S. oranienburg* | 4 | 8,000 | ..... |
| 12 | 22,600 | *S. pullorum* | 5 | 8,400 | ..... |
| 13 | 15,600 | *S. oranienburg* | 6 | 7,400 | ..... |
| 14 | 14,200 | *S. oranienburg* | 7 | 10,000 | ..... |
| 15 | 11,400 | *S. pullorum* | 8 | 4,800 | ..... |
| 16 | 19,600 | ..... | 9 | 7,000 | ..... |
| 17 | 9,800 | *S. pullorum* | 10 | 6,200 | ..... |
| | | | 11 | 8,700 | ..... |
| | | | 12 | 4,200 | ..... |
| | | | 13 | 5,800 | ..... |
| | | | 14 | 6,600 | ..... |
| | | | 15 | 12,200 | ..... |
| | | | 16 | 5,600 | ..... |
| | | | 17 | 10,400 | ..... |
| | | | 18 | 4,800 | ..... |

[j] 28 December 1944.
[k] 29 December 1944.
[l] Standard plate count.

*Salmonella* a difficult task, and permitted survival of relatively insignificant numbers of viable microorganisms.

## DISCUSSION

Extensive microbiological research from several laboratories has established unequivocally that commercial produced liquid whole egg and dried whole egg powder constitute important vehicles for wide dissemination of *Salmonella* organisms. For this reason egg and egg products provide a method for increasing *Salmonella* carrier rates among handlers of these products who are considered the usual source of human salmonellosis in the United States *(1)*. Thus, a situation has been created which, in the author's opinion, indirectly favors potential egg-borne salmonellosis in man.

The interesting work of de Tienne *(4)* surveying commercial practices in certain egg-breaking plants has revealed the lack of efficient sanitary practices during egg-breaking operations. It is not surprising, therefore, that bacteriological investigations have revealed external egg shell surfaces to be one factor in the contamination of liquid eggs with *Salmonella* types. Personnel unwittingly introduce *Salmonella* organisms into egg meats during the breaking-out of eggs which have

TABLE 5

Survival of *Salmonella* in commercial spray-dried, low-moisture, whole egg powder. Plant C, Douthitt-Type Drier

| Hour of operation | SPC [c] per gram | *Salmonella* isolated |
|---|---|---|
| **Liquid whole egg, unheated [m]** | | |
| 1 | 45,000 | *S. pullorum* |
| 4 | 88,000 | ..... |
| 8 | 42,000 | ..... |
| 12 | 151,000 | ..... |
| **Low-moisture whole egg powder processed without aid of preheater [m]** | | |
| 1 | 10,000 | ..... |
| 2 | 4,200 | ..... |
| 3 | 440,000 | ..... |
| 4 | 9,000 | ..... |
| 5 | 780,000 | ..... |
| 6 | 9,800 | ..... |
| 7 | 4,800 | ..... |
| 8 | 12,100 | ..... |
| 9 | 5,500 | ..... |
| 10 | 4,700 | *S. pullorum* |
| 11 | 8,000 | *S. pullorum* |
| 12 | 10,300 | ..... |
| **Liquid whole egg, unheated [n]** | | |
| 1 | 76,000 | ..... |
| 4 | 74,000 | *S. pullorum* |
| 8 | 28,000 | *S. pullorum* |
| 12 | 54,000 | ..... |
| **Liquid whole egg, preheated (flash to 141° F.) [n]** | | |
| 1 | <3,000 | ..... |
| 2 | 4,900 | ..... |
| 3 | 6,000 | ..... |
| 4 | 6,300 | ..... |
| 5 | 4,600 | ..... |
| 6 | 5,700 | ..... |
| 7 | 5,400 | *S. pullorum* |
| 8 | 7,800 | ..... |
| 9 | <3,000 | ..... |
| 10 | 5,500 | ..... |
| 11 | 5,700 | ..... |
| 12 | 5,400 | ..... |
| 13 | <3,000 | ..... |
| 14 | 4,300 | ..... |
| **Pasteurization, holding vat 141-143° F., 6 minutes [n]** | | |
| 1 | <3,000 | ..... |
| 2 | <3,000 | ..... |
| 3 | <3,000 | ..... |
| 4 | 5,000 | ..... |
| 5 | 10,000 | ..... |
| 6 | 4,100 | ..... |
| 7 | <3,000 | ..... |
| 8 | <3,000 | ..... |
| 9 | <4,000 | ..... |
| 10 | <3,000 | ..... |
| 11 | <3,000 | ..... |
| 12 | 3,700 | ..... |
| 13 | <3,000 | ..... |
| 14 | <3,000 | ..... |
| **Low-moisture whole egg powder processed from pasteurized egg [n]** | | |
| 1 | <3,000 | ..... |
| 2 | 27,500 | ..... |
| 3 | <3,000 | ..... |
| 4 | <3,000 | ..... |
| 5 | <3,000 | ..... |
| 6 | <3,000 | ..... |
| 7 | <3,000 | ..... |
| 8 | <3,000 | ..... |
| 9 | <3,000 | ..... |
| 10 | 4,200 | ..... |
| 11 | 4,800 | ..... |
| 12 | 3,400 | ..... |
| 13 | 5,700 | ..... |
| 14 | 5,000 | ..... |

[m] March 1, 1945.
[n] March 2, 1945.
[c] Standard plate count.

been inadequately cleaned of fecal contamination of poultry origin.

The bacteriological work herein presented had been carried out on high quality egg and egg products. Furtherfore, it should be pointed out that commercial processing of this high quality whole egg powder was constantly supervised by an extensive veterinary inspection service. The type of data reported, therefore, are in fact a reflection of the best existing commercial practices in the manufacture of egg powder at the time of these tests.

Production of low-moisture (2%) whole egg powder does not imply the exclusion of *Salmonella* organisms from this product even though processed from a superior-type raw material. It is only when the liquid egg has been preheated to a minimum of 60° C. (140° F.) prior to spray-drying that *Salmonella* organisms have been so reduced in numbers as to make their isolation in egg powder a rarity. Preheating and providing a 2-5 minute pasteurization of liquid egg at not less than 60° C. (140° F.) will in the author's opinion, completely exclude *Salmonella* organisms from manufactured whole egg powder.

It is concluded that technological methods for processing egg powder are available for the total exclusion of *Salmonella* organisms from whole egg powder.

## SUMMARY

1. Liquid whole egg produced from spring-produced (1945), current receipts show a high incidence of contamination with *S. pullorum*.

2. Frozen whole egg used for autumn-winter (1944-1945) spray-drying were also found to be contaminated with several *Salmonella* types, including *S. pullorum*.

3. The commercial practice of preheating liquid whole egg (140° F. and above) prior to spray-drying effectively reduces the incidence of *Salmonella* organisms in whole egg powder.

4. Preheating and short-time pasteurization of high quality liquid whole egg at one less than 60.5° C. (140° F.) for 2-5 minutes will entirely eliminate *Salmonella* organisms from processed egg powder.

5. Examination of 63 lots of high-moisture (5%) whole egg powder revealed a 9.5% incidence of *Salmonella* organisms of the following types: *S. typhimurium, S. montevideo, S. paratyphi B, S. cerro* and *S. oranienburg*.

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# Fruit Flavors[a]

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**A combination of improved methods for the concentration of fruit flavors is described. The known aromatic constituents of the more important fruits are reviewed. A report of analytical findings is given, confirming and extending the known list of volatile flavoring materials naturally occurring in strawberries and raspberries.**

High fruit prices in recent years have made mandatory the adoption of new processing techniques by the extract manufacturer. Fortunately, engineering skills have kept pace with this need and, in spite of the rapidly increasing costs of fruit, it is possible to obtain as much flavor-value per dollar today as when fruit was available at one-half to one-third of today's prices. This truly remarkable achievement must be credited to the careful reporting of many workers through the years and the ability of equipment engineers to apply the lessons learned to practical and economical production. The modern extract manufacturing plant is equipped to process fruits by any one, or a combination of several methods, depending upon the type of fruit and the purpose for which it is to be used.

Concentration by freezing finds a place in this program due to the superiority of the product obtained. A very old idea and the object of many investigations, *(1, 4, 8, 9, 11, 13, 14, 19, 23, 24, 25, 36)* the freezing method has always been retarded by its higher cost, and the limited concentration that may be obtained. Repeated freezings are required to effect maximum concentration and the efficiency decreases rapidly with each successive handling. However, a single freezing may yield a 2- to 3-fold concentration which in some cases makes a valuable addition to more highly concentrated products obtained by other methods.

The method for recovery and concentration of the volatile aromatics from apples and grapes developed by the Eastern Regional Research Laboratory *(22)* has been found applicable, with some modifications, to many other fruits. An essence-recovery unit set up as part of our fruit-processing equipment has been used successfully for several years on raspberries, strawberries, cherries, pineapples, peaches, apricots, currants, and blackberries as well as on apples and grapes. After the removal of these very important volatile materials the remaining juice is generally treated with enzymes to remove pectins, clarified by centrifuging, and concentrated under high vacuum. With the pectins removed, a high degree of concentration is possible. When necessary, fruit may be processed throughout in an inert atmosphere, the juice pressed, deaerated, depectinized, clarified, and a portion concentrated by freezing. Volatile essences may be recovered from the remainder by fractional distillation, this portion then concentrated in high vacuum and all these parts finally combined with extracts or distillates from the press cake. The resulting product contains practically all of the flavor present in the original fruit, highly concentrated, free from troublesome pectinous materials, and relatively stable.

Remarkable as these developments are, it still cannot be said that more flavor can be obtained from the fruit than there is in it, by any of these processes. Concentration by any method does not improve the flavor as supplied to us in the fresh fruit by Mother Nature. As of this moment, a manufacturer of fruit flavors can feel justly proud if he neither loses nor impairs the flavor during concentration. However, the possibility of actually increasing the flavor yield from fruit is suggested in interpretations of work on the study of photosynthesis by use of radioactive tracer elements at the University of California *(3)* and other research laboratories. As pointed out by Hockett *(18)* this work seems to indicate that sucrose is the first and possibly the key product of photosynthesis and that all other products found in plants, including the essential oils of fruits, are derived from sucrose during this involved and little-understood chemical phenomenon. We are permitted to at least dream of encouraging nature to carry some desired photosynthetic reactions more nearly to completion when her "modus operandi" is more clearly understood. Further evidence of the importance of sugar in flavor development is presented by the Eastern Regional Research Laboratories *(34)* in their method for increasing the flavor strength of maple syrup as much as four-fold by a simple reflux. This flavor development is tentatively attributed to the "browning" or Maillard *(21)* reaction. Since this reaction is known to occur in fruits, it would seem promising as an aid also for increasing their flavor strength. While this possibility has been insufficiently explored, limited knowledge indicates that the "browning" reaction is detrimental to the flavor of fruits and to be prevented rather than encouraged.

In Europe, efforts have been made to increase the flavor yield from fruit by fermentation, using, in some cases, rare wine yeasts. While certain yeasts do increase the flavor strength of fruit juices, this increase is accompanied by a loss of fidelity, so much so that it is sometimes difficult to tell by taste what fruit was used as the starting material. Some years ago our laboratories, using many unusual yeast cultures, supplied to us through the courtesy of Dr. Frey of Standard Brands, conducted extensive experiments on strawberry and raspberry concentrates. Slight improvement was obtained with two of the cultures but not sufficient to warrant their use.

It is apparent that further advances in the strength of natural fruit concentrates must await the development of more flavorful fruits, through a more thorough knowledge of those ingredients to which the flavor is due. Such knowledge can also be applied to the development of finer synthetic flavors for use when economics forbid the use of natural flavors alone.

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The extremely small percentages of flavor materials in fruits precludes their easy identification. However, the application of new tools and analytical methods, such as absorption spectrophotometry, chromatography, and ion exchange separations, is now making possible the isolation and identification of these elusive but highly important ingredients.

Published reports show that many of the fruits have been examined analytically, although in some cases superficially.

**Banana.** Kleber *(20)* found amyl acetate in bananas in 1913.

**Apple.** In 1920 Power and Chesnut *(29)* reported their analysis of apples in which they found furfural, acetaldehyde, ethyl alcohol, methyl alcohol, amyl formate, amyl caprylate, formic acid, acetic acid, caproic acid, and caprylic acid. Geraniol was found in McIntosh apples *(31)*. They patended *(5)* a basic formula for apple flavor using these ingredients. In 1950 White *(33)* of the Eastern Regional Research Laboratories examined the volatile essence from apples, prepared in their essence-recovery still and reported that the principal volatile components identified by classes, and the relative quantities of each class present are: alcohols, 92%, (methanol, ethanol, n-propanol, isopropanol, n-butanol, isobutanol, d-2-methyl-1-butanol, and n-hexanol); carbonyl compounds, 6%, (acetaldehyde, acetone, caproaldehyde, and 2-hexenal); esters, 2%, (ethyl butyrate and ethyl caproate). Methanol, ethanol, isopropanol, and n-butanol, and formic, acetic, propionic, and caproic acids were identified as components of other esters. Efforts by them to produce a synthetic apple essence by using a mixture of these compounds were unsuccessful, indicating that probably important constituents are still unidentified.

**Peach.** Power and Chesnut *(30)* also studied the odorous constituents of peaches and reported the presence of acetaldehyde, furfural, probably cadinene, formic acid, acetic acid, linalyl formate, linalyl acetate, linalyl valerate, and linalyl caprylate.

**Grape.** Sale and Wilson *(32)* in 1926 identified methyl anthranilate, acetic acid, ethyl acetate, and other esters in grapes. Later work by Haagen-Smit, Hirosawa, and Wang *(16)* has established the presence of ethyl alcohol, acetaldehyde, leaf aldehyde (2-hexen-1-al), acetylmethylcarbinol, acetic, butyric, caproic, and glyoxylic acids, unidentified waxy and carbonyl compounds, and sulfur in the Zinfandel variety of grapes. Whether the sulfur is present as part of the flavor or remains from spraying could not be positively established.

**Pear.** Miller and Opterwalder *(26)* as well as Harley and Fisher *(17)* reported the presence of acetaldehyde in pears.

**Black Currant Buds.** Glichitch and Igolen *(12)* reported the essential oil from black currant buds to be composed of 85% terpenes, β-pinene, sabinene, caryophyllene, d-cadinene); 6% terpene alcohols, probably sabinol, some terpineols, and a sesquiterpene alcohol; 0.25% phenols, (phenol, β-naphthol); and some acetic acid esters.

**Cherry.** Nelson and Curl *(28)* found benzaldehyde, ethyl alcohol, methyl alcohol, and probably geraniol in Montmorency cherries.

**Pineapple.** Haagen-Smit *(15)* and co-workers, examining pineapples, found ethyl acetate, ethyl alcohol, acetaldehyde, ethyl iso-valerate, methyl-n-propyl ketone, ethyl acrylate, ethyl n-caproate, acetic acid, and methyl β-methyl thio propionate.

**Strawberry.** Coppens and Hoejenbos *(6)* found strawberries to contain acetic acid, n-caproic acid, cinnamic acid, ethanol, diacetyl, ethyl acetate, amyl alcohol, a formic ester, a butyric ester (probably ethyl), a caproic ester (ethyl or methyl), acetic esters, a benzoic ester, n-hexanol, ethyl salicylate, borneol, alpha terpineol, terpin, a saturated fatty acid $C_{18}H_{26}O_2$, m.p. 55.5 — 56° C.), and a keto compound ($C_{10}H_{18}O_3$). The probable presence of acetylmethylcarbinol, acetophenone, and isofenchyl alcohol was indicated.

Our laboratory has confirmed the presence of acetophenone, diacetyl, cinnamic acid, and acetic acid. In addition, *n*-butyraldehyde, *cis*-terpinol hydrate, and probably ethyl-acetoacetate have been identified and an interesting high molecular weight aldehyde or ketone was separated and is still to be identified.

**Raspberry.** Raspberries have been investigated to a greater extent than any other fruit. The first recorded work was by Elze *(10)* in 1929. He reported the presence of an unknown paraffin (M.P. 43-44° C.), anisaldehyde, irone, and nerol. The last three ingredients are very powerful flavoring materials and are usually found in imitation raspberry compounds; irone coming from oil orris; nerol from neroli oil or lavender, bergamot, rose, etc.; and anisaldehyde either added directly or resulting from the oxidation of anethole in anise or fennel oils. This suggests that Elze may have inadvertently worked with an adulterated product since all later experimenters have failed to confirm his work.

Coppens and Hoejenbos *(7)* reported their extensive work in 1939 concluding that acetic, n-caproic, and benzoic acids, diacetyl, ethyl alcohol, ethyl acetate, isoamyl alcohol, benzaldehyde, phenyl-ethyl alcohol and benzyl alcohol were present in raspberries; that acetylmethylcarbinol, coumarin, menthone and a salicylate were probably present and that irone, nerol, and anisaldehyde were not present.

In 1942, Bohnsack *(2)* verified most of the work done by Coppens and Hoejenbos and in addition found isobutyl alcohol and 3-hexen-1-ol (beta-gamma hexenol). The latter is very characteristic and powerful in odor. Since it was present in only minute quantities, he felt it had little effect on the odor of raspberries. Bohnsack was very diligent in his work especially in regard to the presence of nerol, anisaldehyde, and irone, but was unable to find them.

Wilson *(35)* of the U. S. Department of Agriculture has done a great deal of work to determine if β-ionone occur naturally in raspberries. Since this aromatic resembles raspberry in aroma, it has often been found as an adulterant in supposedly authentic fruit extracts. However, he was unable to find even a trace in raspberry juice. More recently, Naves *(27)* has reported the presence of β-ionone in an extract made from the marc of raspberries. Whether this is found only in the presscake, or is present only in certain European vari-

eties has not been established but the quantities found were negligible.

In our laboratory we have identified the following constituents of black raspberries: formic acid, acetic acid, benzoic acid, hydrocinnamic acid, acetone, acetaldehyde, diacetyl, benzaldehyde, isobutyraldehyde, menthone, catechol, ethyl alcohol, isoamyl alcohol, butyl alcohol, isobutyl alcohol, benzyl alcohol, menthol, ethyl acetate, ethyl acrylate, and ethyl salicylate.

We were unable to confirm the presence of coumarin, phenylethyl alcohol, $\beta$-ionone, irone, anisaldehyde, and nerol, as reported by other workers.

Important components of the various fruits still remain to be confirmed or identified. In this connection, the importance of sulfur compounds must be mentioned. These evil-smelling compounds for the most part can be quite pleasant in very dilute solutions. Haagen-Smit and his co-workers have already identified sulfur in pineapples *(15)* and more recently have shown that it is a possible component of the flavor of Zinfandel grapes. *(16)*. Sulfur compounds have played a major part in our research on the aroma of coffee and, indeed, already make up a good percentage of some of our well-known flavors. Garlic, onion, horseradish, and mustard owe the bulk of their flavor to sulfur compounds that we know and can synthesize. Part of the flavor of steak and soya sauce is due to sulfur compounds although in many cases the exact structure of the sulfur-bearing compound is not known. The odor of some of the volatile fruit essences obtained from the juices indicates the possible presence of traces of volatile sulfur compounds. We are, in our continuing research on fruits, attempting to isolate some additional powerful flavoring ingredients from their natural sources. This is a formidable task, however, since many of these compounds are present in minute quantities. The work is so tedious and time-consuming that no single laboratory can quickly accomplish the desired results. However, the many workers in the industry are bringing to light invaluable information at an accelerated pace. The infinite variations in the proportions in which these known ingredients may be combined presents an intriguing challenge to the expert flavor blender.

Until recent years the flavor chemist has been essentially an artist. He has found that certain aromatic chemicals, essential oils and natural products when properly compounded will make a synthetic flavor that resembles with remarkable fidelity, in many instances, the flavor, and aroma of certain fruits. The work on the composition of the flavor-bearing portions of several fruits has verified the presence of aromatics that have been used by expert flavor men for years. To date not enough work has been done so that the organic chemist can produce, with his findings, a flavor of superior fidelity to that of the flavor-creator. However, each new finding by the organic chemist adds to the art of the flavor chemist and they are now working together and producing vastly superior products. We have found that the organic chemist's findings in our Aromatic Research Laboratories have been a great aid in producing superior synthetic flavors. On the other hand, the flavor-creator with his trained sense of smell has been able to detect compounds by odor, thus aiding the organic chemist not only in identification of natural products but in the development of new synthetic aromatics. This cooperation of organic chemist and flavor-creator coupled with the work and cooperation of developmental engineers has resulted in natural and synthetic food flavors of greater economy, greater fidelity and greater stability.

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# Recommended Standards for Scoring and Measuring Opened Egg Quality*

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**A pictorial chart is presented showing the appearance quality of opened eggs that meet the requirements of the U. S. standards for quality of individual shell eggs. This chart provides a uniform scale of quality differences and is intended to simplify and standardize egg quality measurement. Various measurements of interior egg quality are discussed. The Haugh unit was found to be the simplest and most applicable quantitative measurement to apply to the interior quality conditions shown in the pictorial chart. A calculator for Haugh units is presented which provides means of converting egg quality data among several quality criteria.**

The need for uniform standards for scoring and measuring opened eggs for quality determination becomes apparent after reviewing the literature pertaining to studies of egg quality. Numerous methods of measuring egg quality in the laboratory have been used in the past, resulting in data from many studies that were difficult to compare. Photographic standards were included in these methods and have been used in the laboratory by research workers. Some of them have been published. The first United States standards for quality of individual shell eggs were proposed in 1923 and were adopted in 1925 *(16)*. There have been several revisions since that time, the latest in 1946 *(18)*, but only the 1943 *(17)* revision referred to the appearance of opened or broken-out eggs. These standards are based on factors observed when an egg is held before a candling lamp. The choice of the factors used in the development of the standards was undoubtedly influenced by the broken-out quality of the eggs since early work in the U. S. Department of Agriculture by Pennington, Jenkins, and Betts *(12)* referred in text and illustration to both the appearance of shell eggs before the candling lamp and their quality when broken out.

The purpose of this article is to present the necessary graphs, measurements, and calculations that will make it possible to evaluate the quality of opened eggs in a uniform manner. In addition, a pictorial chart is presented showing opened eggs that are typical of the appearance of eggs that meet the requirements of the four United States standards for quality of individual shell eggs (AA, A, B, and C). These recommended standards for scoring and measuring opened egg quality provide: (1) uniform methods for determining and converting egg quality measurements in the laboratory and (2) means whereby the application of standards for quality of individual shell eggs before the candling lamp may be carried out more uniformly and accurately.

## THE INTERIOR QUALITY PICTORIAL CHART[d]

### Objectives

Although several pictorial charts of egg quality have been presented in the past *(6, 14, 22)*, none of them has been accompanied by a clear statement of the objectives to be served. Since no detailed pictorial chart of opened egg quality has been designed to represent the U. S. standards for quality of individual shell eggs, it was considered desirable to prepare such a chart. The major objectives of this chart are: (1) conformity with U. S. quality standards, (2) uniformity of scale, and (3) presentation of pictures that are typical of the appearance of eggs normally found in market channels.

**Conformity with U. S. Quality Standards.** The 1943 revision of the U. S. standards included a designation of the Van Wagenen and Wilgus *(22)* chart score[e] expected in each of the four qualities when the eggs were opened. However, all reference to these scores was removed in the 1946 revision because the Van Wagenen chart was not designed to represent U. S. quality standards. Figure 1 shows the appearance characteristics of opened eggs that meet the requirements of the U. S. standards for quality of individual shell eggs when the candling factors relative to albumen and yolk condition are properly applied. It is well known, of course, that candling of eggs does not reveal sufficiently reliable indices to predict the broken-out quality with perfect accuracy. It is hoped that, by using the standards shown in Figure 1, candling accuracy can be improved. A critical analysis of the candling factors used in the standards has recently been published by Baker and Forsythe *(1)*.

In Figure 1, pictures 1, 2, and 3 represent AA quality; pictures 4, 5, and 6, A quality; pictures 7, 8, and 9, B quality; and pictures 10, 11, and 12, C quality. It is suggested that these numbers be used as "score" values when judging opened egg quality.

**Uniformity of Scale.** Primarily for purposes of analyzing egg quality data, it is necessary to have a uniform scale of quality differences. Since this report concerns the U. S. standards it was necessary to find a quality "unit" so that these reference standards differed by some common multiple of that unit.

At least six methods have been used in the past to estimate the quality of opened eggs on a quantitative basis: (a) yolk index *(15)*, (b) albumen height *(23)*, (c) albumen index *(6)*, (d) albumen area index *(11)*,

*Report of a study supported in part by the Research and Marketing Act.

[a] Bureau of Animal Industry, Beltsville, Maryland.

[b] Poultry Branch, Production and Marketing Administration, Washington, D. C.

[c] Bureau of Plant Industry, Soils and Agricultural Engineering, Beltsville, Maryland.

[d] Copies of the Interior Quality Pictorial Chart in color and full size can be obtained from the Market Services Division, Poultry Branch, PMA, U. S. Department of Agriculture, Washington, D. C.

[e] Sometimes called "Cornell Chart score."

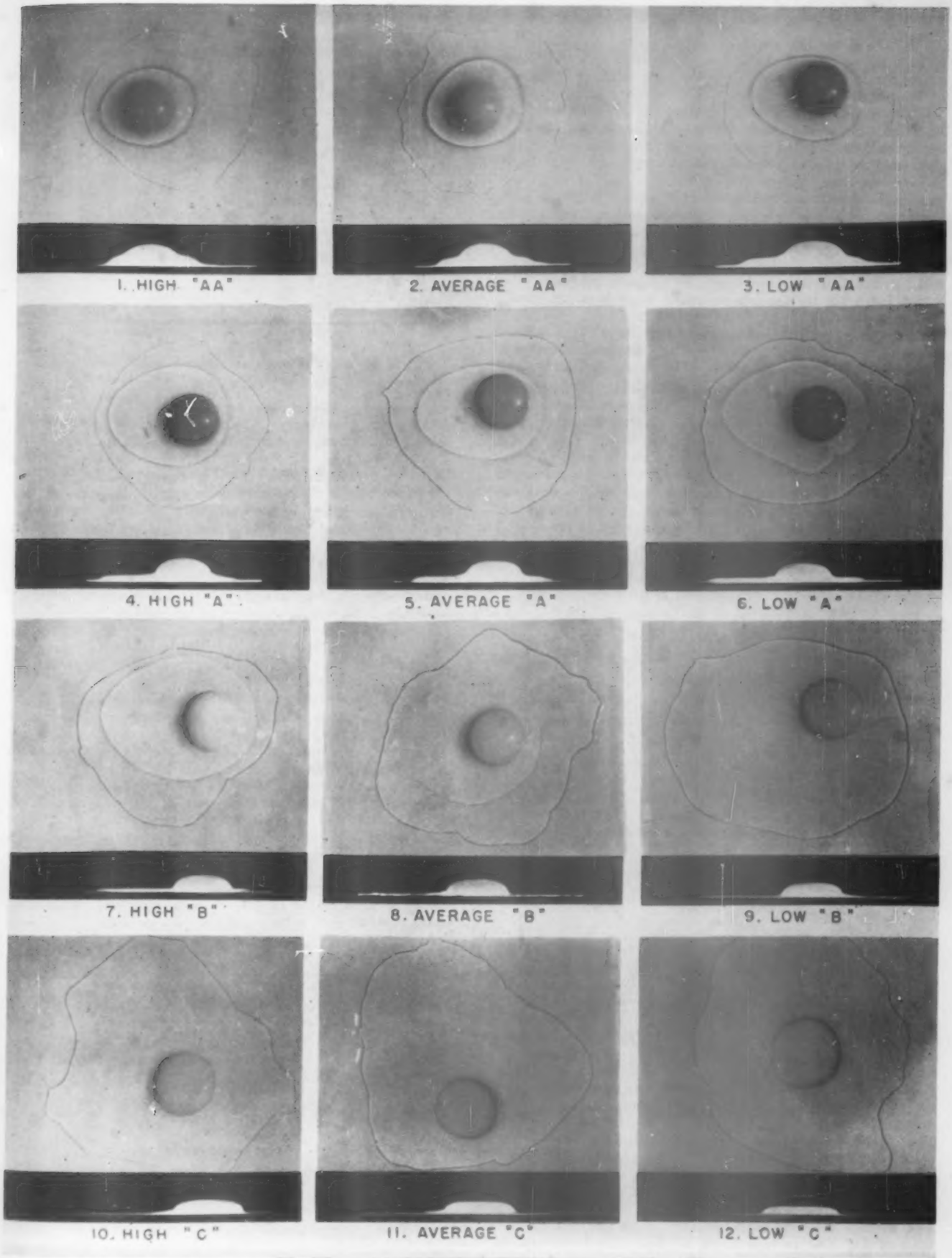


FIG. 1. Eggs selected to represent the appearance characteristics that meet the requirements of the U. S. standards for quality of individual shell eggs.

(e) percentage of thick and thin white *(8)*, and (f) Haugh units *(4)*.

**Yolk Index.** This was the first quantitative measure of egg contents used to estimate quality. The yolk index was proposed by Sharp and Powell *(15)* and was defined as the ratio of the height to the width of the yolk measured after the yolk had been separated from the albumen. It has been found that the yolk can be satisfactorily measured without removing it from the albumen *(2, 3)*. Since the yolk index in newly laid eggs tends to vary less than albumen measurements *(7, 10, 13, 20)*, it is most useful for estimating the effects of aging. However, yolk index does not appear to be the determining factor in the appearance of opened eggs. The condition of the albumen is a primary factor since an egg having poor albumen quality is not improved much in overall appearance by the presence of a high index yolk. In the Van Wagenen chart, for exmaple, all yolks have a high index but the appearance quality depends on the condition of the thick albumen. Furthermore, low yolk indices are seldom, if ever, encountered in eggs having good albumen quality. Therefore poor appearance quality is more often reflected in albumen measurements than in yolk measurements.

**Albumen Height.** Wilgus and Van Wagenen *(23)* proposed this method as a means of reducing error in scoring, when using their pictorial chart. They reached the conclusion that albumen height alone or albumen height multiplied by the ratio of the egg weight to 56.7 g. (2 ounces) did not give a linear relationship with their scoring system. Since the relationship is not linear, albumen height as a measure of egg quality does not provide a uniform scale. Figure 2 shows the relationship between albumen height and score of the eggs used in the USDA chart (Figure 1).

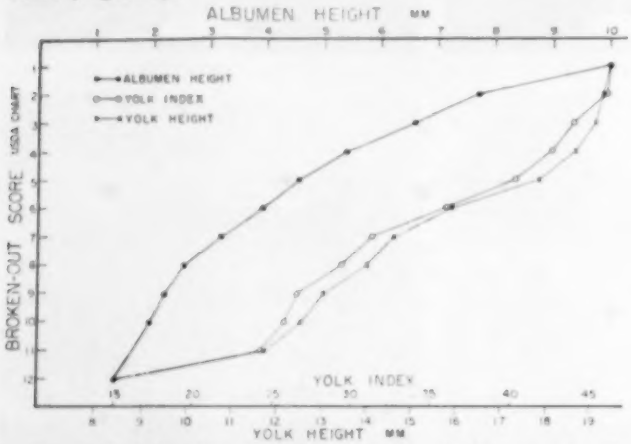


FIG. 2. Relationship of albumen height, yolk index and yolk height to the broken-out quality scores of the eggs used in the USDA chart (Figure 1).

**Albumen Index.** Developed by Heiman and Carver *(6)*, this measurement was originally the ratio of the albumen height to the average width of the firm albumen. It was found later *(24)* that with proper modification for egg size, the albumen height and egg weight could be fitted to a nomogram giving the albumen index without the necessity of measuring albumen width. The standard for the albumen index was a series of five photographs showing various stages of egg quality. The albumen indices of the eggs used in the USDA chart are shown in Figure 3. Since the relationship is not linear, unmodified albumen index determinations cannot be averaged to compare with average USDA chart scores or the USDA qualities because of the lack of a uniform scale. To illustrate this point, assume that 10 eggs weighing 2 ounces each are opened, scored, and measured. The 10 albumen indices are found to be 152, 143, 124, 135, 85, 62, 54, 40, 22, and 15; the scores to be 1, 1, 1, 1, 3, 4, 5, 6, 8, and 10. The average albumen index is 83.2, which corresponds to a score of 3.0. The average score, however, is 4.0. In addition, the albumen index cannot be used in its original form, where albumen width measurements are required, on eggs which have no definite outline of thick white when opened.

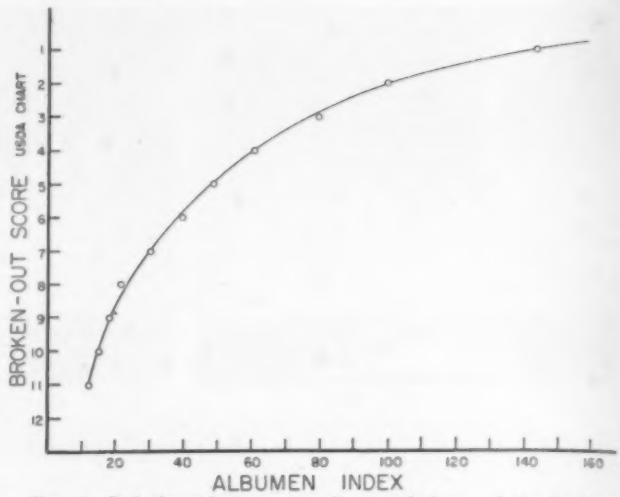


FIG. 3. Relationship between albumen index and the broken-out quality scores of the eggs used in the USDA chart (Figure 1).

**Albumen Area Index.** Parsons and Mink *(11)* originally developed this method and it was later modified by Hoover *(9)*. It is essentially an estimate of the amount of spreading observed in the thick albumen. Since it is a more time consuming method than some of the other measurements and because it cannot be used on eggs which do not have a well defined thick albumen outline, no attempt was made to apply it to the eggs pictured in the USDA chart.

**Percentage of Thick and Thin White.** This method of meas- This method of measuring quality was first proposed by Holst and Almquist *(8)*. It has not been found to be closely associated with appearance quality except when used as a measure of deterioration in storage experiments *(7, 21)*. For this reason, together with the fact that it is a time consuming operation, no attempt was made to correlate the percentage of thick white with the score of the eggs in the chart.

**Haugh Units.** Without elaboration or definition of quality, Haugh *(4)* stated that he found egg quality to vary as the logarithm of the albumen height. He developed a correction factor for egg weight, multiplied the logarithm of the corrected albumen height by 100 and called the resulting figure the "Haugh unit" of egg quality. Figure 4 shows the relationship between Haugh units and the score of the eggs used in the USDA chart. These points fit very closely to a straight line showing that Haugh units provide a uniform scale of quality differences. The eggs pictured differ by approximately 8 Haugh units or 0.08 in the logarithms of their albumen heights. It was assumed, therefore, that an ideal chart would picture eggs fitting exactly on the line shown in Figure 4 and that Haugh units could be used as the mathematical expression of the quality of opened eggs.

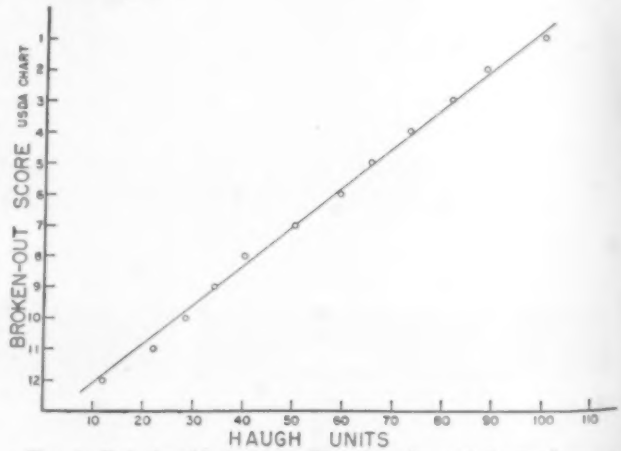


FIG. 4. Relationship between Haugh units and the broken-out quality scores of the eggs used in the USDA chart (Figure 1).

Of these various methods, the simplest and most rapid to use is the measurement of egg weight and albumen height. Since neither albumen height alone nor albumen index provide a uniform scale of quality differences among the eggs pictured in the USDA chart (Figure 1), the logical choice is the Haugh unit. A repetition of Haugh's formulas is therefore in order:

For 2-ounce eggs:

$$HU = 100 \text{ Log } H \quad (1)$$

To corect for egg weight:

$$HU = 100 \text{ Log } [H - \frac{\sqrt{G(30W^{0.37} - 100)}}{100} + 1.9] \quad (2)$$

Which can be simplified to:

$$HU = 100 \text{ Log } (H - 1.7W^{0.37} + 7.6) \quad (3)$$

The following formulas convert Haugh units and albumen height to "quality scores" (Q. S.):

$$Q.S. = 13.35 - (HU)/8 \quad (4)$$

For 2-ounce eggs

$$Q.S. = 13.35 - 12.5 \text{ Log } H \quad (5)$$

To correct for egg weight and using the simplification of formula 3:

$$Q.S. = 13.35 - 12.5 \text{ Log } (H - 1.7W^{0.37} + 7.6) \quad (6)$$

Where HU is Haugh units, H is the albumen height in millimeters, G is 32.2, W is the egg weight in grams, and Q. S. is the quality score on USDA chart.

**Presentation of Pictures That Are Typical of the Appearance of Eggs Normally Found in Market Channels.** This objective is necessitated by the fact that the general appearance of opened eggs is subject to considerable variation without any material change in quality. The Van Wagenen chart *(22)*, for example, shows eggs opened within 4 hours after laying. Since there is little variation in yolk index (height/width) *(15)* among these eggs, the difference in quality results from the variations in albumen condition (height). The low quality eggs in this chart present an entirely different general appearance than low quality eggs that are more than a few days old where low yolk indices as well as low albumen heights are observed. For this reason some difficulty has been experienced in the use of the Van Wagenen chart for scoring low quality eggs that are normally seen in market channels. The Van Wagenen chart, however, is very useful for scoring eggs less than 24 hours old.

It was decided to picture eggs in the USDA chart (Figure 1) with decreasing yolk height as score increases to more nearly typify the eggs usually encountered in market channels. Figure 2 shows the relationship of quality score to yolk height and yolk index for the eggs used in the USDA chart. The relationship is neither uniform nor linear. No attempt was made to select eggs showing a uniform scale of yolk index differences because of the unreliability of this factor in determining appearance quality.

## INTERIOR QUALITY CALCULATOR[r]

A simple and rapid means of determining Haugh units from measurements of egg weight and albumen height is provided in the interior quality calculator for eggs shown in Figure 5.

In addition, the calculator shows the relationship of these factors to USDA chart scores, USDA qualities and Van Wagenen chart scores. The calculator is a circular adaptation of the nomogram developed by Haugh *(5)*. It is used by placing the smaller disc on top of the larger one so that their center points coincide. After measuring the weight and albumen height of an egg, rotate the smaller disc so that the weight pointer coincides with the weight of the egg. The albumen height is then opposite the Haugh unit for that egg, and USDA chart score, Van Wagenen chart score, and USDA quality will also be indicated by reading straight outward from the Haugh unit value already obtained.

The Haugh unit values of the Van Wagenen scores are not the same on the calculator as that given in Haugh's original publication *(4)*. A new relationship was established because when eggs in the Van Wagenen chart were compared with eggs in the USDA chart, there was considerable difference in appearance between eggs having similar Haugh unit values. Therefore, a re-examination of Haugh's formula for the Haugh units of Van Wagenen scores was undertaken. It was learned

[r] Vitroline copies of the interior quality calculator for eggs may be obtained at nominal cost from the Marketing Services Division Poultry Branch, PMA U. S. Department of Agriculture, Washington, D. C.

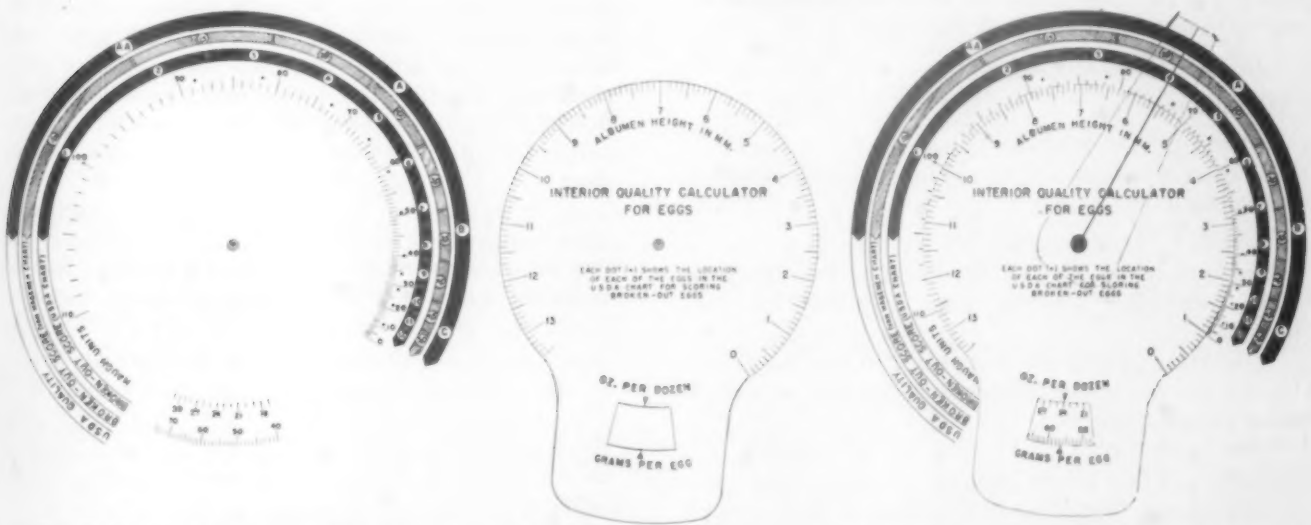


FIG. 5. The interior quality calculator for eggs. When egg weight and albumen height are known, Haugh units, USDA scores, Van Wagenen scores, and USDA qualities can be calculated. The calculator also serves as a means of converting data among any of these quality criteria.

from Van Wagenen *(19)* that the albumen heights of the eggs pictured in his chart had not been determined. Since this means of getting Haugh unit values was lacking, Van Wagenen scores were equated to USDA scores for which albumen height and Haugh units were known. Since each of the 12 pictures in the USDA chart covers a range of 8 Haugh units, then each of the 9 pictures in the Van Wagenen chart should cover a range of 10⅔ Haugh units. This assumes that the two charts cover a similar range of appearance quality, and that both are uniform scales over the range covered. On that basis new Haugh unit values were calculated for the Van Wagenen scores. With the new values, eggs in the two charts with similar Haugh units were again compared and found to be similar in appearance. Further support for this change was obtained when the Haugh unit values of scored and measured eggs published by Wilgus and Van Wagenen *(23)* were averaged and plotted. The results are shown in Figure 6.

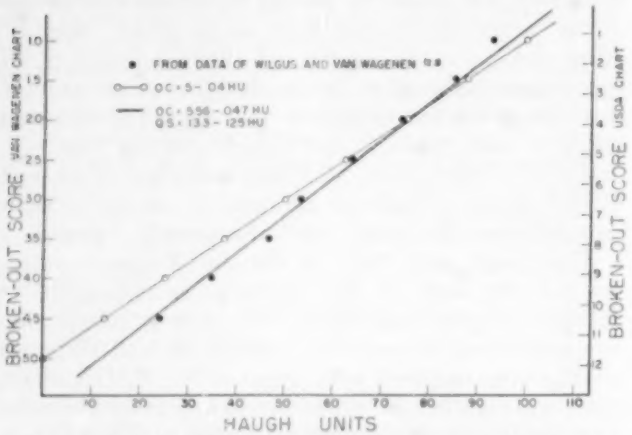


FIG. 6. Relationship between Haugh units and the formulas used for equating Haugh units and broken-out quality scores on both the Van Wagenen and USDA charts.

These values fit the new line much better than the one proposed by Haugh.

This change requires that Haugh's formula for equating Van Wagenen score and Haugh units which was O.C. = 5 — .04 HU should read:

$$O.C. = 5.56 - .047\ HU \qquad (7)$$

For 2-ounce eggs:

$$O.C. = 5.56 - 4.7\ \text{Log}\ H \qquad (8)$$

To correct for egg weight and using the simplification of formula 3:

$$O.C. = 5.56 - 4.7\ \text{Log}\ (H - 1.7W^{0.37} + 7.6) \qquad (9)$$

where O.C. is the observed condition or Van Wagenen score. All other symbols were explained following formula 6.

It is believed that more accurate conversions from USDA scores to Van Wagenen scores can be made if these formulas are used.

One further note of explanation is required. The calculator, at first glance, appears to give a wider range for high quality eggs than for low quality eggs. Such is not the case. There are exactly 8 Haugh units per quality score on the USDA chart regardless of the space on the circumference of the calculator disc required to accommodate these 8 Haugh units. The Haugh unit scale is a logarithmic scale multiplied by 100 and by nature appears to be compressed at one end and expanded at the other. A simple reversal of the scales on a circular calculator is not possible (that is, placing the albumen height on a logarithmic scale and the Haugh units on an arithmetic scale).

Egg quality data in terms of albumen index have appeared in many publications. Figure 7 shows the

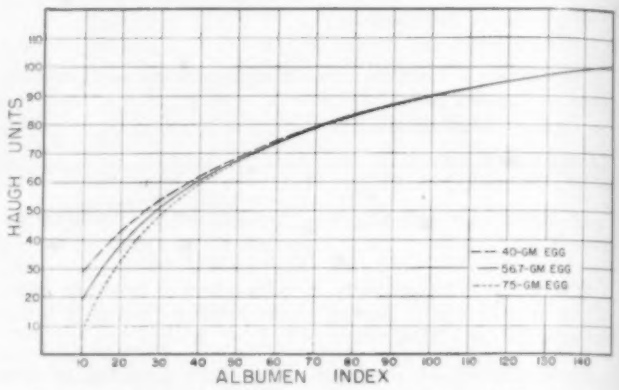


FIG. 7. Relationship between albumen index and Haugh units.

relationship between Haugh units and albumen index. The graph can be used to relate albumen indices to Haugh units and also to USDA scores, USDA qualities or Van Wagenen scores.

## SUMMARY

A pictorial chart is presented showing opened eggs representing the four qualities (AA, A, B and C) of the United States standards for quality of individual shell eggs. The purpose of the chart is to furnish reference standards for scoring the quality of opened eggs. Its objectives are to (1) conform with U. S. standards, (2) show a uniform scale of quality differences, and (3) present pictures of eggs that are typical of the quality they represent.

The quantitative methods of estimating egg quality are reviewed briefly. It is pointed out that Haugh units provide a uniform scale of quality values whereas albumen height alone or albumen index do not. Yolk index, albumen area index, and percentage of thick white were considered to be too time consuming or not closely enough associated with the appearance quality of opened eggs to be used as supplements to the USDA chart.

An interior quality calculator is presented which provides a rapid means of determining Haugh units. It also provides conversion from USDA qualities to Van Wagenen scores to USDA scores to Haugh units. A conversion graph showing the relationship between Haugh units and albumen index is also presented.

### Acknowledgment

The authors are indebted to Mr. Harvey B. Mohr, U. S. Department of Agriculture photographer, for the excellence of his work in the development of the Interior Quality Pictorial Chart.

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# Expanded Rice Product. A New Use for Parboiled Rice[a]

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(Manuscript received June 6, 1951)

**An expanded rice product is described which is a ready-to-eat cereal product made by heating dry parboiled rice in vegetable oil, shortening, or in a stream of hot air. The expanded crisp grains can be made rapidly and easily from commercially available raw material. Production would involve a single processing step in easily fabricated equipment. This product would offer an additional outlet for rice in the edible field.**

The expanded rice product described herein is prepared by expanding or "puffing"[b] parboiled rice. When the dry gelatinized grains of parboiled rice are heated in oil or air, they expand in a few seconds to several times their original volume and change from a dense, hard, glassy material to a crisp porous product which is thoroughly cooked and ready to eat. Raw white rice will not expand when treated under the same conditions. The expanded parboiled rice can be eaten without additional processing and may therefore be considered for use as a ready-to-eat cereal product or as a base for confections or other mixed food items.

## PRODUCT AND PROCESS

Parboiled rice *(2,3,7,8)* is made commercially by steeping rough rice (paddy) in water, steaming under pressure to gelatinize the starch, then drying the treated grain and milling it to remove hull and bran layers. The glassy appearance of this material can be seen in Figure 1 (top). The details of parboiling methods vary somewhat *(4,5,14)*, but the main effects are reported *(6,10,12)* to be (a) higher yield of whole grains or head rice during milling, (b) improvement of nutritional value, and (c) resistance to insect infestation.

Parboiling of rice has been practiced in the Orient for many years, primarily in India and Burma, but the procedures were not standardized to any extent. In some cases, rough rice was simply steeped in hot water for several hours, then dried in the sun. The original intent was to facilitate removal of the hulls and any nutritional improvement was incidental. In the past decade, parboiled rice has received considerable attention in this country and as a result of technical advancement the process has been adopted by three large commercial plants.

The expanded rice product described here is not to be confused with other ready-to-eat cereals prepared from rice, such as puffed rice *(1)*, oven-expanded or "blistered" flakes or shaped kernels *(9,13)*, or "popped" rice *(11)*. The familiar puffed rice is prepared by a "gun-puffing" process wherein the grain is subjected to high pressure and temperature, and puffed by the sudden release of pressure. The oven-expanded or "blistered" product requires a combination of cooking, adding various flavorings, drying with careful control of moisture content, flaking or shaping, and finally toasting in ovens. Whole grain is used to some extent, but many products are first made into a dough, then shaped as desired before toasting. The texture of these products is radically different from the product described here. "Popped" rice is prepared by heating a glutinous or waxy type of rice (usually as raw rough rice, with hull and bran layers intact) and the product is similar to popcorn.

In the process for making expanded rice, parboiled rice is heated to about 200° C. (392° F.) in vegetable oil, or about 250° to 300° C. (482° to 572° F.) in a blast of air. When heated in oil, the short-grain parboiled rice expands to about six times its original volume in about ten seconds (Figure 1, middle). The product is light and fluffy and contains about 5 to 10% of oil. The increase in volume of the short-grain parboiled rice puffed in air at 250° C. (482° F.) is about five-fold (Figure 1, lower), and at 300° C. (572° F.) about six-fold. The rice can be puffed in an oven, but this treatment is not as satisfactory as placing it in a vertical tube through which heated air is forced at a velocity sufficient to agitate the grains. When the grains have expanded they are carried up the tube by the air stream as a result of increased buoyancy, and can be collected in a cyclone separator. Parboiled pearl (short-grain) rice puffs in about 20 seconds at 250° C. (482° F.), or in about 10 seconds at 300° C. (572° F.), when heated in air. The product contains only the original oil content of the rice, which is usually about 0.5 to 1%.

[a] A report of work done under the Research and Marketing Act of 1946.

[b] The terms "expand" and "puff" will be used interchangeably throughout this paper.

FIG. 1. Appearance of processed rice. (Top) Parboiled short grain rice. (Middle) Expanded rice product prepared in oil at 200° C. (392° F.). (Lower) Expanded rice product prepared in air at 250° C. (482° F.). (Approx. 3 x natural size.)

## PRODUCTION METHODS AND EFFECTS OF VARIATIONS

The object of this phase of the study was to produce an expanded rice product of maximum volume and most pleasing texture. Important factors governing the degree of expansion of parboiled rice in either oil or air were found to be the temperature of the puffing medium and the moisture content of the rice. Tests were therefore undertaken to establish the relationship of these variables to puffing volume and to determine ranges where maximum increase would occur. Both long- and short-grain types of rice were used in these tests. In general, the short-grain type expanded to a greater volume when treated under the same conditions, possibly because of varietal differences, but more likely because of the shape of the grains. Short-grained parboiled rice from Arkansas gave results similar to rice grown and processed in California.

**Expansion in Oil.** To determine the effect of temperature on the volume of expanded product, portions of parboiled rice (11% moisture) were heated in vegetable oil at different temperatures between 140° and 250° C. (284° to 482° F.) until maximum puffing was attained in each case or until substantially all moisture had been removed. The time varied from about 8 to 60 seconds, but when heated at 200° C. (392° F.), the rice was fully expanded in about 10 seconds. The puffed samples were drained, cooled on absorbent paper, and their bulk volumes measured. Volume increases (ratio of volume of product to volume of rice) of a representative series of tests are illustrated in Figure 2. It is observed that maximum puffing occurs in the range 200° to 220° C. (392° to 428° F.), and that no expansion takes place at 140° C. (284° F.) or below. Volume increases may vary by as much as 0.5 unit depending on proportions of rice and oil used, but by as little as 0.2 unit when the quantities of rice and oil are held constant.

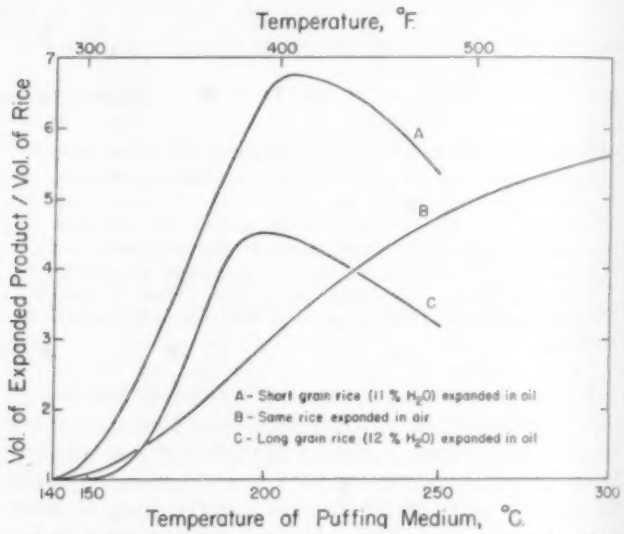


FIG. 2. Effect of temperature on the volume of expanded rice product prepared in oil and in air.

To study the effect of moisture, portions of parboiled pearl rice containing 6 to 21% moisture were puffed in oil at 200° C. (392° F.). Volume relationships were determined as described above. The moisture content (originally 11%) of portions of a bulk sample of rice was increased by spraying with a fine mist of water and was lowered by drying in a forced-draft oven at 45° to 50° C. (113° to 122° F.). Final moisture levels were estimated by weight difference. After treatment, all samples were tempered or conditioned in capped jars for 10 days, with occasional mixing, to allow even distribution of water before puffing. Following the tempering period, actual moisture contents were determined

by drying a 20-gram sample of whole-grain rice for 16 hours in a forced-draft oven at 105° C. (221° F.). Portions of each sample of rice were puffed in oil at 200° C. (392° F.). The effect of moisture content on the volume of puffed product is shown in Figure 3.

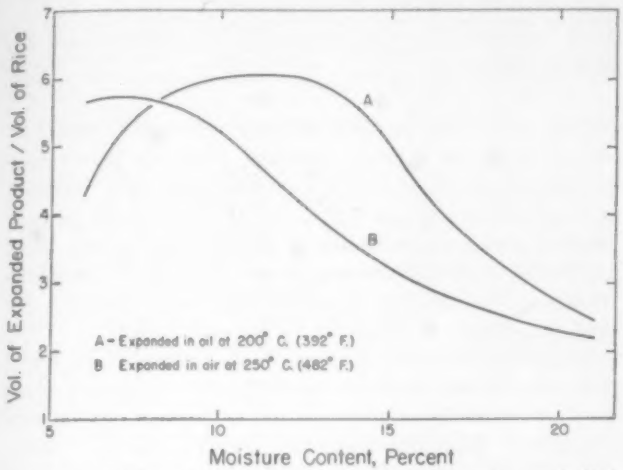
Vol. of Expanded Product / Vol. of Rice
Moisture Content, Percent
A
B
A = Expanded in oil at 200° C. (392° F.)
B Expanded in air at 250° C. (482° F.)

FIG. 3. Effect of moisture content of short-grain parboiled rice on the volume of expanded rice product prepared in oil and in air.

From the standpoint of practical preparation of expanded rice in oil, parboiled rice having a moisture content between about 8 and 14 percent (which includes the normal range as received) would be the most desirable starting material. The volume of product prepared from rice containing moisture above or below this range diminishes rapidly and the texture becomes progressively tougher.

**Expansion in Air.** Tests on the expansion of parboiled rice in air were performed in a 3-inch (internal diameter) tube through which heated air was forced at a velocity of about 15 feet per second. This was sufficient to produce gentle agitation of the rice grains on a supporting screen. Portions of parboiled pearl rice (11% moisture) were puffed under these conditions at air temperatures from 150° to 300° C. (302° to 572° F.). In addition, samples of rice with different moisture contents were puffed at 300° C. (572° F.). Although no study was made of the influence of air velocity, it would be expected that this factor, as well as the temperature of the air stream, would have an effect on the degree of expansion.

Figure 2 shows the effect of air temperature on the volume of the expanded rice. Although no puffing occurred at 140° C. (284° F.) or below, the volume steadily increased as the temperature was raised to the highest value used. A study of the effect of moisture content on the volume of product showed that the optimum level is about 8 to 9%, when the rice was expanded in air (Figure 3). Thus, partial drying of the milled parboiled rice would be desirable before expanding it by means of hot air.

## STORAGE STABILITY CHARACTERISTICS

For storage tests, samples of parboiled pearl rice were expanded in air and in peanut, corn, rice, cottonseed, and hydrogenated cottonseed oils. In addition, rice was puffed in three portions of peanut oil each containing 0.01% of one of three different types of commercial antioxidant: nordihydroguaiaretic acid, butylated hydroxyanisole (plus synergists), and ethyl hydrocaffeate. A portion of each sample was stored in an oven at 60° C. (140° F.). Samples prepared in hydrogenated cottonseed oil showed no evidence of rancidity development during storage for 8 weeks at this temperature, but were definitely rancid after 9 weeks. Rancid odors were detected in the other air- and oil-puffed samples (containing no added antioxidants) after 11 to 15 days of storage at this elevated temperature. The effectiveness of the addition of 0.01% antioxidant varied, but in general the period of stability of the oil-puffs was increased about two-fold.

A duplicate series of samples was stored in tightly capped jars under prevailing laboratory conditions. The puffed product prepared in hydrogenated cottonseed oil (no added antioxidants) was still fresh and very crisp after seven months, whereas the samples puffed in the common liquid vegetable oils (peanut, corn, etc.) became rancid in from 3 to 5 months under the same conditions; little or no advantage of one oil over the other was suggested by these results. Ethyl hydrocaffeate was not satisfactory as an antioxidant. However, samples prepared in oil containing 0.01% of the other two antioxidants have remained fresh and crisp for seven months, and it is expected that these plus the one prepared in hydrogenated fat will remain fresh for a still longer period. Therefore, if the expanded rice product was prepared by heating parboiled rice in liquid vegetable oils containing an effective antioxidant or in hydrogenated fats, it may be predicted that the product would be stable enough to satisfy commercial requirements.

## USES

The expanded rice product prepared in either oil or air is thoroughly cooked and has flavor characteristics distinct from other ready-to-eat rice cereals. The puffed grains could be used as a breakfast cereal or as an ingredient in confections or other prepared foods. The oil-puffed rice can be salted and eaten with no additional treatment. The pleasing flavor and texture of these rice products have received favorable comment. The satisfactory processing and stability characteristics, together with the results of informal taste tests, indicate that expanded rice product would be a worthwhile addition to the list of ready-to-eat food items.

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# Pasteurized Fresh Whole Pickles. II. Thermal Resistance of Microorganisms and Peroxidase[a,b]

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**As a part of the investigations on the pasteurization of fresh whole pickles, the present studies were conducted to obtain information on the degree of microbiological contamination after various pasteurization times, the thermal resistance of causative spoilage organisms, and the influence on these thermal death times of varying concentrations of spice oils, salt, and acetic acid.**

**Occasionally, cases have been reported where although microbiological counts were low indicating adequate heat treatment for their control, off — or stale—flavors have developed in this type of pickle during storage. Consequently, the possible relationship of the heat-resistant enzyme peroxidase to this off-flavor development was investigated. Results correlating organoleptic acceptability with minimal values of peroxidase activity are presented.**

Although the heat resistance characteristics of microorganisms causing spoilage in nonacid foods (pH above 4.5) have been, and will continue to be a fertile field for investigation, relatively little work has been done on those organisms responsible for spoilage in acid foods (pH 4.5 or below). This is in part due to the public health significance of the nonacid foods as well as to the lack of realization on the part of processors of acid foods that the quality of their products might be measurably improved if the factors governing process times were better understood and controlled.

Etchells and Jones *(7)* investigated the effect of reducing simultaneously both the acid and sugar contents of pickling liquor on the destruction of test organisms after 15 minute processes at temperatures up to 71° C. (160° F.) A definite correlation was found between the number of survivors and the acid content of the liquors at temperatures of 49° C. (120° F.) and 54° C. (130° F.). At 60° C. (140° F.) and 66° C. (150° F.) all test inocula were destroyed in the full strength liquor although survivors were found in the diluted liquors. At 71° C. (160° F.) all test inocula were destroyed irrespective of liquor concentration.

According to Etchells and Jones *(8)*, if fresh dill pickles are covered with hot dill liquor at a temperature of 71-76.5° C. (160-170° F.), which will give cut-out values of six to eight grains of vinegar and 2.5-3.0% salt, a process of 15 minutes at 73° C. (165° F.) after the brine temperature at the center of the jar reached 73° C. (165° F.) proved adequate in preventing spoilage.

The role that enzymes play in processed acid foods has recently been reviewed by Kaplan, Esselen, and Fellers *(10)* and Nebesky, Esselen, Kaplan, and Fellers *(12)*. The former reported that the peroxidase enzyme from salt stock pickles was quite heat resistant at temperatures below 85° C. (185° F.). Fifty percent sucrose solutions exhibited a definite protective effect on the thermal resistance of peach and pear peroxidase, whereas 5% vinegar solutions markedly reduced the heat resistance of cucumber pickle peroxidase.

Nebesky, Esselen, Kaplan, and Fellers *(12)* found that peroxidase from commercial packs of fresh whole Kosher style dill pickles varied widely in its thermal resistance. Thermal death time studies on this enzyme at a temperature of 88° C. (190° F.) indicated a range of from 40 to 45 minutes in one lot of pickles to between 150 and 200 minutes in a second. This difference was attributed to variations in peroxidase concentration within different lots of the raw cucumbers. Further studies revealed that after one year of storage at room temperature, residual peroxidase activity was demonstrable in quart jars of fresh whole Kosher style dill pickles that had been processed 35 minutes at 85° C. (185° F.) but not in those processed for 40 minutes. Thus, it was evident that peroxidase which survived the original processing was not destroyed during one year of storage at room temperature.

## EXPERIMENTAL

As described by Esselen, Anderson, Ruder, and Pflug *(5)*, during the 1948, 1949, and 1950 pickle seasons, 54 laboratory and commercial packs of fresh whole cucumber pickles were packed in one-quart glass containers.

When packs were made at nearby commercial plants, unprocessed samples were also secured to obtain data on the effectiveness of commercial washing and soaking conditions on microbiological populations of the pickle. Samples of the day's regular commercial pack which had been processed according to the packer's regular procedure were also obtained and examined.

As soon as possible after processing at least one jar from each processing level, in addition to the unprocessed and commercially processed samples, were examined for total numbers of viable organisms, relative peroxidase activity, pH, acid content, and organoleptic acceptability. The remaining jars were stored at room temperature of about 22° C. (72° F.) and observed frequently during the first month of storage for spoilage. They were re-examined at the end of eight months for enzymic activity and quality acceptability.

Microbiological studies were made, after thorough shaking of the sample jar, by preparing appropriate dilutions of the pickle brine and plating out on Difco Nutritive Caseinate Agar containing bromcresol purple as recommended by Etchells and Jones *(9)*. The use of this media enabled the total count to be further broken down into relative numbers of acid-forming and peptonizing bacteria.

After incubating at 32° C. (90° F.) for 72 hours the plates were counted. Table 1 illustrates the effect of various processing times at 82° C. (180° F.) on the original numbers of organisms present on the cucumbers. In similar packs prepared by adding 20 p.p.m. of mustard oil (allylisothiocyanate) to the regular

[a] Contribution No. 806, Massachusetts Agricultural Experiment Station.

[b] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 19, 1951.

TABLE 1

Total [c] number of bacteria in commercial and laboratory packs of fresh whole Kosher style dill pickles after various processing times at 82° C. (180° F.)

| Sample | Time in minutes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| | Number of bacteria | | | | | | | | |
| 1949. Commercial pack | 69,000,000 | 500,000 | 313,000 | 2,580 | 195 | 265 | 190 | 140 | 50 |
| 1949. Laboratory pack | 6,150,000 | 9,620 | 4,340 | 3,890 | 1,080 | 1,060 | 675 | 565 | 260 |
| 1950. Commercial pack | 410,000,000 | 946,500 | 77,900 | 425 | 175 | 95 | 90 | 65 | 65 |
| 1950. Laboratory pack | 3,000,000 | 3,070 | 10,170 | 2,220 | 1,490 | 395 | 210 | 245 | 515 |

[c] The indicated counts represent averages of 9 laboratory and 5 commercial packs in 1949 and 8 laboratory and 15 commercial packs in 1950.

brine, there was no significant difference from control packs in either preventing spoilage on storage or in decreasing the number of organisms after a given process time at 82° C. (180° F.).

It should be noted that in all determinations only one jar from each processing level was plated out, and therefore differences from these reported counts would be reflected by variations in initial contamination or in brine-pickle ratios.

From the jars of pickles which spoiled during storage, a total of 78 mixed cultures were obtained which were later identified as being made up of yeasts and members of the following bacterial genera: *Bacillus, Microbacterium, Lactobacillus, Leuconostoc,* and *Micrococci.* Preliminary screening tests revealed that only 15 of these mixed cultures had a thermal resistance of 10 minutes or more at 71° C. (160° F.) in a weak brine containing 0.19% acetic acid and 1.7% salt. Eight of these cultures were destroyed between 15 and 50 minutes at 71° C. (160° F.), although two other cultures had thermal death times in this brine of between 100 and 120 minutes at this temperature.

Thermal death time studies in this investigation were carried out in an apparatus similar to that described by Anderson, Esselen, and Fellers *(1)* using a modification of the multiple tube method proposed by Esty and Williams *(6)*. After heating and cooling the thermal death time tubes, the contents were plated out in Difco Dextrose Agar, incubated for 72 hours at 22° C. (72° F.) and examined for growth.

From the 15 mixed cultures, a total of 33 pure cultures were isolated. Upon inoculation of the 33 organisms into sound jars of fresh Kosher style pickles and tubes of pickle brine containing 0.84% acetic acid and 2.5% salt, only three produced typical spoilage characteristics. The causative spoilage agents were then isolated and identified as a yeast and two Lactobacilli. Spoilage in the pickles by Lactobacilli was characterized by cloudiness of the brine and subsequent sedimentation while the yeast fermentation produced gas, cloudiness and sedimentation.

Although the two isolated Lactobacilli and the yeast were capable of growing in pickle brines containing 0.12 to 0.14% acetic acid and 5.5% salt, further thermal death time studies at 54.5° C. (130° F.) revealed that only the yeast was capable of withstanding one minute in a brine containing 0.5% acid and 5.0% salt. In view of these findings only this yeast was used in subsequent studies on the effect of essential oils, acid and salt concentrations on its thermal death times.

## RESULTS

**Influence of Acid Concentration on Thermal Death Times.** The thermal death times of the yeast in brine containing 5.0% salt and 0.5, 1.0, and 1.5% acetic acid were determined.

The pH values of the 0.5, 1.0, and 1.5% acid brines were 2.9, 2.6, and 2.5, respectively. Results of the thermal studies are presented graphically in Figure 1. At 60° C. (140° F.) the effect of increasing the acid content of the brine to 1.0 and 1.5% acetic acid resulted in decreases of 55 and 78% of the thermal death time in the control brine (0.5% acetic acid).

The $F_{160}$ and z values of these curves are tabulated in Table 2. Herein the symbol $F_{160}$ represents the number of minutes required to destroy the test organism in a given medium at the specified temperature of 71° C. (160° F.). The letter z designates the slope of the thermal death time curve expressed as the number of degrees Fahrenheit passed over by the thermal death time curve in traversing one logarithmic cycle.

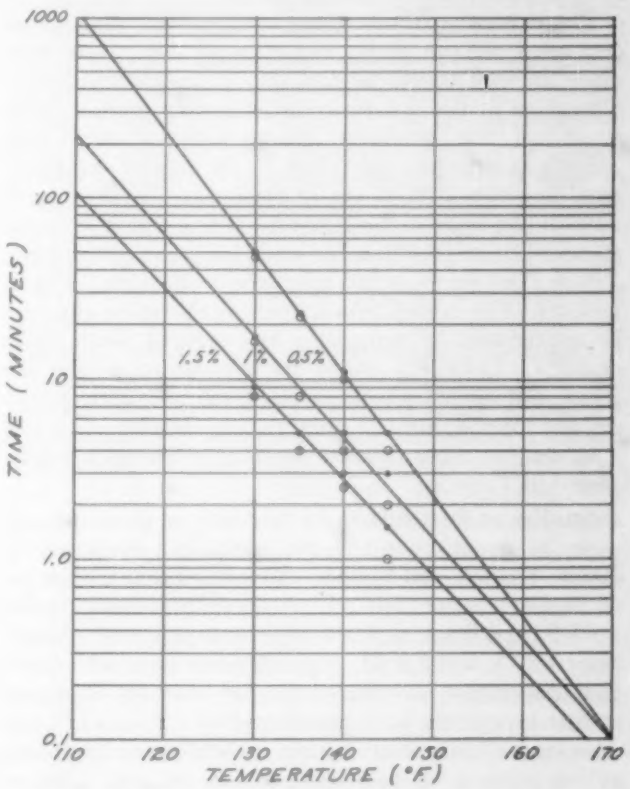


FIG. 1. Effect of 0.5, 1.0, and 1.5% acetic acid on the thermal death times of the test yeast organism in brine containing 5.0% salt.

**Influence of Salt Concentrations on Thermal Death Times.** The effect on the thermal resistance of the test organism of maintaining the acetic acid content of the brine content at 0.5% and varying the salt concentrations from 5.0 to 15.0% was studied. Whereas salt concentrations of 7.5 and 10.0% appeared to exert a slight protective effect and the 15.0% level reduced the thermal death times somewhat, the changes were not considered significant. $F_{160}$ and z values of these thermal death time curves are presented in Table 2.

**Influence of Spice Oils on Thermal Death Times.** Inasmuch as certain spices are known to possess bacteriostatic or even bactericidal properties, a study of the effect on the thermal resistance of the test organism of a

TABLE 2

$F_{100}$ and z values of the test yeast organism as influenced by various concentrations of acetic acid, salt, and spice oils

| Substrate | $F_{100}$ value | z value |
|---|---|---|
| | *min.* | *° F.* |
| Brine containing 0.5% acetic acid,5% salt | 0.50 | 15.0 |
| Brine containing 1.0% acetic acid, 5% salt | 0.36 | 18.0 |
| Brine containing 1.5% acetic acid, 5% salt | 0.24 | 19.0 |
| Brine containing 0.5% acetic acid, 7.5% salt | 0.70 | 16.5 |
| Brine containing 0.5% acetic acid, 10% salt | 0.70 | 16.5 |
| Brine containing 0.5% acetic acid, 15% salt | 0.44 | 14.5 |
| Brine containing 0.5% acetic acid, 5% salt, 258 p.p.m. dill spice oils | 0.16 | 12.5 |
| Brine containing 0.5% acetic acid, 5% salt, 2580 p.p.m. dill spice oils | 0.10 | 17.0 |
| Brine containing 0.5% acetic acid, 5% salt, 20 p.p.m. mustard oil | 0.14 | 14.0 |

Kosher dill spice oil flavoring[4] and of mustard oil (allylisothiocyanate) was carried out.

The particular dill flavoring used in these studies was composed of both garlic and dillweed oils which were made up with vegetable gum into a standard emulsion. Therefore in the recommended flavoring level of 1000 p.p.m. of the emulsion, there were actually only 258 p.p.m. of spice oils, and in the 10,000 p.p.m. of emulsion, only 2580 p.p.m. of spice oils. Thermal death time studies were carried out on the test organism in the standard brine (0.5% acetic acid, 5.0% salt) containing 258 or 2580 p.p.m. of dill spice oils or 20 p.pm. of mustard oil. The added lethal effect of the spice oils may be appreciated by comparing the thermal death times at 60° C. (140° F.) which for the control brine, 258 p.p.m. dill oil, 20 p.p.m. mustard oil, and 2580 p.p.m. dill are 11, 6, 4, and 1.7 minutes, respectively. $F_{100}$ and z values for these thermal death time curves are presented in Table 2.

**Studies on Peroxidase.** In the study on pickle peroxidase the quantitative test for peroxidase employed by Reddi, Esselen, and Fellers *(14)* was modified. Ten ml. of distilled water, 5.0 ml. of phosphate-citrate buffer (pH 5.1), 1.0 ml. of 0.3% hydrogen peroxide (Merck Superoxol), and 1.0 ml. of pickle brine were added to a test tube which was placed for five minutes in a constant temperature bath maintained at 25° C. (77° F.). The start of the reaction time was taken as beginning at the moment of half-delivery into the test tubes of one ml. of a 1% aqueous solution of orthophenylenediamine hydrochloride (opda) which had been adjusted to pH 5.1 with sodium hydroxide. Then at the end of five minutes, two ml. of a saturated solution of sodium bisulfite was added to inactivate the peroxidase.

In the presence of peroxidase and hydrogen peroxide, opda was oxidized to the orange-red end-product phenazine with the intensity of the coloration at the end of the reaction period being dependent on the enzyme concentration if other factors are kept constant.

The use of pickle brine in lieu of the aqueous extract of comminuted pickle suggested by Kaplan, Esselen, and Fellers *(10)* accelerated the testing for peroxidase activity. This substitution was accepted after comparing colorimetrically the relative enzymic activities of enzyme extracts prepared by blending 25 grams of pickles and 44 ml. of distilled water to that obtained from 25 ml. of pickle brine taken from the same jars and diluted to an equivalent volume. In all tests made in this manner the peroxidase activity of the brine samples was greater than that from the aqueous pickle extract.

If comparisons between subsequent samples are to be made, it is important that the time intervals in the procedure be adhered to closely. Also due to the fact that aqueous solutions of opda are subject to rapid autooxidation, it is necessary to prepare fresh solutions every five hours.

The results of these experiments are presented in Table 3. It should be noted from the results of these experiments presented in Table 3 that in each pack of pickles there were processing levels which resulted in acceptable pickles from a quality standpoint. This was true even though there was definite residual peroxidase activity still active after an eight-month storage period. Integration of these critical processing levels into $F_{100}$ values was presented by Esselen, Anderson, Ruder, and Pflug *(5)* in Part I of this study.

In order to obtain an objective and more quantitative method of scoring the residual enzymatic activity, a second modification of the method of Reddi, Esselen, and Fellers *(14)* was developed. Using 125 ml.-erlenmeyer flasks in place of test tubes, the color developed at the end of the five minute reaction period was extracted. Because excessive quantities of ethyl acetate were required for complete extraction of phenazine, isoamyl alcohol was tried and found very satisfactory.

Although isoamyl alcohol possessed a high partition coefficient and the use of only three small portions gave almost complete extraction, five extractions were made in all experiments to be sure that all oxidized opda was removed and to allow for variations in concentrations of peroxidase. Furthermore, as the extract of phenazine in isoamyl alcohol was found to fluoresce yellow under ultraviolet light, the absence of fluorescence in isoamyl extracts was used as an indication of the completeness of extraction of phenazine. Transmission measurements of the extracts were subsequently made in an Evelyn photoelectric colorimeter with a 420 filter and with a blank adjusted for 100% transmission. The blanks were prepared in like manner except that the enzyme extract was boiled for ten minutes, cooled, and made up to its original volume. That phenazine was quite stable in isoamyl alcohol was evidenced by the fact that colorimeter readings did not vary over a 15 hour period.

Quantitative results on residual peroxidase activity expressed as percent transmission in some of the stored pickles packs are presented in Table 3.

## DISCUSSION OF RESULTS

Although the pasteurization of both laboratory and commercial packs of fresh pickles in quart jars for 15 to 25 minutes at 82° C. (180° F.) resulted in destruction of the vast majority of acid-forming and yeast microorganisms, residual bacterial counts, largely peptonizing types, of 95 to 3800 organisms per ml. of brine were encountered which were relatively unaffected by additional processing up to 40 minutes. It was noted

[4] Supplied as "Kosh-A-Dill" spice oils by the Magnus, Mabee, and Reynard Company.

TABLE 3

Relation of processing times and temperatures to peroxidase concentration and flavor acceptability of fresh whole Kosher style dill pickles

| Pack No. | Ingoing brine acidity | Process temp. | Process time | Transmission | Enzymic activity | Flavor |
|---|---|---|---|---|---|---|
| | % | ° F. | min. | % | color value | |
| 1 | 0.8 | 180 | 10 | ..... | 4 | Off |
| | | | 15 | ..... | 4 | Off |
| | | | 20 | ..... | 4 | Acceptable |
| | | | 25 | ..... | 3 | Acceptable |
| | | | 30 | ..... | 3 | Acceptable |
| | | | 35 | ..... | 3 | Acceptable |
| | | | 40 | ..... | 2 | Acceptable |
| 4 | 1.2 | 180 | 20 | 42.2 | 5 | Off |
| | | | 25 | 52.2 | 5 | Off |
| | | | 30 | 55.2 | 4 | Acceptable |
| | | | 35 | 67.1 | 4 | Acceptable |
| | | | 40 | 90.3 | 4 | Acceptable |
| 6 | 2.0 | 180 | 15 | 59.1 | 4 | Off |
| | | | 20 | 66.0 | 4 | Acceptable |
| | | | 25 | 73.2 | 3 | Acceptable |
| | | | 30 | 79.2 | 3 | Acceptable |
| | | | 35 | 92.1 | 2 | Acceptable |
| | | | 40 | 94.3 | 1 | Acceptable |
| 7 | 3.0 | 180 | 25 | 59.1 | 2 | Acceptable |
| | | | 30 | 68.2 | 2 | Acceptable |
| | | | 35 | 92.3 | 1 | Acceptable |
| | | | 40 | 100.0 | 0 | Acceptable |
| 10 | 3.0 | 180 | 5 | ..... | 3 | Off |
| | | | 10 | ..... | 3 | Off |
| | | | 15 | ..... | 3 | Off |
| | | | 20 | ..... | 2 | Off |
| | | | 25 | ..... | 1 | Acceptable |
| | | | 30 | ..... | 1 | Acceptable |
| 14 | 1.6 | 180 | 20 | 58.1 | 3 | Off |
| | | | 25 | 62.2 | 3 | Acceptable |
| | | | 30 | 68.3 | 3 | Acceptable |
| | | | 35 | 88.2 | 1 | Acceptable |
| | | | 40 | 93.2 | 1 | Acceptable |
| 15 | 1.8 | 180 | 15 | 57.1 | 3 | Off |
| | | | 20 | 61.3 | 3 | Slight Off |
| | | | 25 | 64.2 | 3 | Acceptable |
| | | | 30 | 74.1 | 2 | Acceptable |
| | | | 35 | 90.1 | 1 | Acceptable |
| | | | 40 | 93.1 | 0 | Acceptable |
| 19 | 1.6 | 165 | 20 | ..... | 5 | Off |
| | | | 25 | ..... | 5 | Off |
| | | | 30 | ..... | 5 | Off |
| | | | 35 | ..... | 5 | Off |
| | | | 40 | ..... | 5 | Acceptable |
| | | | 45 | ..... | 5 | Acceptable |
| | | | 50 | ..... | 3 | Acceptable |
| | | | 55 | ..... | 3 | Acceptable |
| 18 | 1.6 | 195 | 8 | ..... | 5 | Off |
| | | | 12 | ..... | 5 | Off |
| | | | 16 | ..... | 5 | Off |
| | | | 20 | ..... | 4 | Off |
| | | | 24 | ..... | 4 | Off |
| | | | 28 | ..... | 3 | Acceptable |
| | | | 32 | ..... | 2 | Acceptable |
| | | | 36 | ..... | 1 | Acceptable |
| 31 | 1.73 | 195 | 5 | ..... | 5 | Off |
| | | | 10 | ..... | 4 | Off |
| | | | 15 | ..... | 4 | Off |
| | | | 20 | ..... | 4 | Slight Off |
| | | | 25 | ..... | 3 | Slight Off |
| | | | 30 | ..... | 2 | Acceptable |
| | | | 35 | ..... | 1 | Acceptable |
| | | | 40 | ..... | 1 | Acceptable |
| 12 | 1.6 | 212 | 9 | ..... | 4 | Off |
| | | | 12 | ..... | 3 | Slight Off |
| | | | 15 | ..... | 2 | Acceptable |
| | | | 18 | ..... | 1 | Acceptable |
| | | | 21 | ..... | 0 | Acceptable |
| 21 | 1.6 | 212 | 6 | ..... | 4 | Off |
| | | | 9 | ..... | 4 | Off |
| | | | 12 | ..... | 4 | Off |
| | | | 15 | ..... | 3 | Slight Off |
| | | | 18 | ..... | 1 | Slight Off |
| | | | 21 | ..... | 0 | Acceptable |
| | | | 24 | ..... | 0 | Acceptable |

further that these residual bacterial levels did not change significantly over an eight-month storage period at 22° C. (72° F.).

These findings are in agreement with those of Etchells and Jones *(9)* who reported that a total count of a few thousand resistant, aerobic, spore-type bacteria are normally found in unspoiled pickle products.

It is interesting to note that whereas in both the 1949 and 1950 seasons, the total bacterial counts on the raw unwashed cucumbers used in laboratory packs totalled between 3.0 and 6.5 million organisms per ml. of brine, counts on the commercial cucumbers after soaking and washing were between 69 and 410 million organisms per ml. of brine. That the increase in numbers was due to heat-labile organisms is evident from the equilibration of numbers in both packs after a 15 minute process. However there is the possibility of these organisms building up in cuts or bruises of the cucumber, and of chance packing causing these cut areas to be pressed tightly against a neighboring pickle. As it is generally recognized that a product with a high level of microbiological contamination requires a longer process than one with relatively few organisms, such areas would require a greater sterilizing treatment, but, because of their positioning, might receive less thermal treatment than adjacent areas exposed directly to he brine.

In the studies of the effect of various concentrations of acetic acid on the heat resistance of the selected yeast organism, the thermal death time decreased with increasing amounts of acid. Inasmuch as the addition of 0.5, 1.0, and 1.5% acetic acid resulted in brine pH values of 2.9, 2.6, and 2.5, respectively, and as Bigelow and Cathcart *(4)* pointed out that the hydrogen ion had been termed the most toxic of substances, these findings were not unexpected. However, data presented by Esselen et al. *(5)* on the amount of pasteurization required to prevent spoilage indicated that contaminating organisms survived a more severe heat treatment under actual processing conditions than the test organism did under the established experimental conditions. In the latter, the acid content and pH values of the brine remained constant throughout the thermal death time runs; whereas, in the processing of pickles, the initial acid concentration of the brine begins to decrease in the first few minutes as it equalizes into the pickles. The extent of the decrease in acid concentration may be illustrated by the following experiment. Packing pickles in brine with an initial acetic acid concentration of 1.95%, lots of six jars of pickles were processed at five minute intervals from five to forty minutes at a temperature of 82° C. (180° F.). At the end of each processing interval the jars were removed and their entire brine contents immediately transferred to separate jars and subsequently titrated. The average acid concentrations of the six jars at the end of 0, 5, 10, 15, 20, 25, 30, 35, and 40 minute processes at 82° C. (180° F.) were 1.95, 1.79, 1.62, 1.46, 1.37, 1.30, 1.25, 1.14, and 1.12%, respectively.

Thus the concentration of only 1.13% acetic acid in the brine represents a reduction of 42% of the brine's initial acid content after a 40 minute process. Accompanying changes in the hydrogen ion concentration

would be expected to result from the decreased amounts of acid and the possible buffering effect of substances leached out from the pickles.

In many experimental packs it was observed that the whole pickles were often pressed either firmly together or tightly against the jar. In such cases not only may the rate of heat penetration be considerably retarded but as the brine does not come in contact with these localized areas, the lethal effect of the acid may be lost.

The application of heat equivalent to providing a sterilizing value of 36 minutes at 71° C. (160° F.) based on the slowest heating jars encountered, as indicated by Esselen et al. *(5)*, appeared to provide sufficient heat treatment to provide the degree of sterilization necessary to take care of the above-mentioned variables.

The influence on the heat resistance of the test yeast of varying the salt content of a brine containing 0.5% acetic acid from 5.0 to 15% was also studied. Even though relatively high concentrations were employed (15%), there was little or no effect on the thermal death times. Similar findings were reported by Tanner *(15)* who stated that Dougherty found no influence on the thermal resistance of yeast of salt concentrations ranging from 5% to saturated solutions.

In recent years the use of spice oils rather than whole spices has become rather widespread in the pickle industry. Baumgartner *(3)* stated that the effect of elevated temperatures on the toxic action of spices or microorganisms did not appear to have been investigated. Anderson, Esselen, and Fellers *(1)* reported that clove oil caused significant reductions in thermal death times of spores of *Baccillus thermoacidurans* in tomato juice. Kosker *(11)* also found that 10 p.p.m. of mustard oil lowered thermal death times of *Saccharomyces ellipsoideus* in buffer solutions by more than 50%.

In the present study the results of adding dill spice oils in concentrations of 258 p.p.m. (acceptable flavoring level) and 2580 p.p.m. and mustard oil at a level of 20 p.p.m. were evidenced by greatly reduced thermal resistance of the test yeast. In the brines containing 258 p.p.m. of dill spice oils and 20 p.p.m. of mustard oil, reductions in their thermal death times over that in the standard (0.5% acetic acid and 5.0% salt) brine were 45 and 63%, respectively. The 84% reduction in thermal resistance of the brine containing 2580 p.p.m. of dill spice oils over that of the standard brine is of theoretical interest only as this concentration resulted in considerable overspicing.

A comparison of the time and temperature relationships in Table 3 to those shown by Esselen et al. *(5)* to be adequate for the control of microbiological spoilage revealed that a much more severe heat treatment is required for the complete destruction of peroxidase than for microbiological control. These results also indicated that in order to prevent off-flavor of the type attributable to peroxidase activity, it was only necessary to provide sufficient heat treatment to reduce the peroxidase activity to a low level than to destroy it completely.

## CONCLUSION

From a total of 27 comparable laboratory and commercial packs of fresh whole pickles, data were obtained on the degree of contamination, the heat resistance of isolated spoilage organisms, and on the influence of varying concentrations of spice oils, acetic acid, and salt on the thermal death times of a test yeast organism. Pasteurizing for 25 minutes at 82° C. (180° F.) reduced the initial counts of microorganisms to a level which did not change materially on sustained heat treatments. Although concentrations of salt ranging from 5.0 to 15% exhibited little effect on the thermal death times of the test yeast organism in brine solutions, the addition of mustard oil (allyisothiocyanate) and various concentrations of acetic acid and dill spice oils markedly increased the lethal effect of a given heat treatment.

Investigations of the correlation of off-flavor development with residual peroxidase activity revealed a definite relationship between these two factors. Adequate processing to reduce the original peroxidase concentration to a certain critical value yielded pickle packs that did not develop off-flavors on storage.

Inherent variations encountered in this type of product which might influence the effectiveness of the pasteurization treatment are pointed out and discussed.

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# New Products from California Clingstone Canning Peaches[a]

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**In experiments conducted to devise uses for surplus canning cling peaches, it was found that canned Julienne strips, canned sauce, and a canned sieved (puree) were particularly satisfactory and promising. Other products studied were granules, powdered peaches, vacuum-dried "nuggets," an ice cream base, barreled peaches, and thickened canned sliced peaches for use in pies.**

Commercially-grown cling peaches are of two types. One is soft-fleshed and juicy when ripe and the flesh is usually white or pink in color. The skins usually show a pink or red blush. Such cling peaches are grown primarily for use fresh as sliced peaches or for eating fresh out of hand. Some varieties of this type are slip skins and can be peeled after steaming, or, if thoroughly ripe, steaming is not necessary. They are not very satisfactory for commercial canning.

The second type is the yellow canning cling peach. This is grown in California on a large scale and in a considerable number of varieties for commercial canning. The fruit is usually much larger than that of the type previously mentioned. The flesh is yellow to golden yellow in color and very firm. It withstands processing (sterilization) by heat after canning extremely well, the texture actually being improved thereby. In the raw condition the flesh is too firm for comfortable eating even when the peach is well ripened. Consequently it withstands fresh shipment from the orchards to the canneries and storage at the canneries exceptionally well. Often the fresh peach travels by truck 150 miles before being canned. The skin is stick-tight and cannot be loosened by plain steaming, and for this reason lye-peeling is used commercially and hand-peeling in the home. Very few California canning clings are sold fresh for use in the home. The season extends from mid-July to mid-September.

California cling peaches are canned halved or sliced, and diced when in combination with other fruits such as in fruit cocktail and fruit mix, and quartered for salad. The commercial packs of these products in recent years are shown in Table 1.

[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 20, 1951.

TABLE 1

Commercial packs of cling peaches in various forms in cases (After Canners League, 1950 and 1951)[b]

| Year | Halves and sliced | Fruit cocktail | Fruits for salad | Mixed fruits (fruit mix) |
|---|---|---|---|---|
| 1945 | 12,574,557 | 5,111,630 | (Not permitted in 1945) | 528,552 |
| 1946 | 17,604,924 | 6,906,684 | 546,843 | 703,918 |
| 1947 | 15,325,281 | 4,917,779 | 511,709 | 151,429 |
| 1948 | 15,240,816 | 4,577,857 | 325,602 | 52,380 |
| 1949 | 17,757,966 | 3,604,186 | 448,464 | 146,874 |
| 1950 | 14,428,886 | 6,827,874 | 563,860 | 69,139 |

[b] From mimeographed tables issued each spring by Canners League, San Francisco.

For many years the production of cling peaches for canning has frequently exceeded the demand, and limitation of the pack by various Federal, State, or industry control plans has been invoked in order to prevent over-supply of the canned fruit with resulting ruinously low prices. For example, during the 1950 season the peach growers and canners cooperated under the California State Agricultural Marketing Act to not only limit the pack but to up-grade the quality.

In order to find uses for peaches not canned in years of over-production, experiments have been conducted in this laboratory on various canned, frozen, and dried products.

## CANNED JULIENNE PEACHES

During the 1947 and 1948 seasons small amounts of canning cling peaches were pitted, lye-peeled, washed free of lye, and cut into Julienne strips by means of a small restaurant-size "shoe-string" potato cutter *(7)*. They were canned in syrups of 25° and 40° Brix, exhausted, sealed, and processed at 100° C. (212° F.). Those packed in the 40° Brix syrup were considered of about the proper sweetness *(7, 9)*.

During the 1949 season a semi-commercial-scale lot was canned in a local cannery. Halved, lye-peeled mid-summer clings were cut in a commercial-size vegetable shoe-string cutter into Julienne strips about ⅛ x ⅛ inch in cross section; 11¾ oz. packed per No. 1 tall can; 38° Brix syrup added to fill; exhausted about 5 minutes in live steam; sealed; processed at 100° C. (212° F.) for 24 minutes in an "A and B" continuous canned fruit processor; and cooled about 3 minutes in cold water in an "A and B" continuous cooler. A slightly shorter cook might have been preferable in order to give a firmer product.

The net drained weight several weeks after canning averaged about 11.0 oz. and the Brix degree of the syrup 18.6°.

About 500 cans of the product with a short questionnaire were given to Berkeley housewives through the cooperation of two large "serve yourself" grocery stores. Within a month 261 had replied. Some of the housewives failed to answer all the questions, not an uncommon experience.

In respect to sweetness, 202 replies were favorable; 44 found the product too sweet, and 15 not sweet enough. As to general appearance, 203 replies were very favorable, 24 unfavorable, and 11 moderately favorable. In respect to thickness of strips 171 were favorable; 66 unfavorable, 44 stating they were too thin in cross section. Some, 53, thought the No. 1 tall can too small; 148 found it of satisfactory size; and 12 found it too large for a family of 2 persons.

The following uses were reported: in fruit salad; in short-cake; "as is" as a dessert; with breakfast cereals; in upside-down cake; made into sauce; with cottage cheese as salad; ice cream topping; in peach pie; in cobbler; various puddings; in gelatin dessert and gelatin salad; in mousse; and chopped and frozen in home-made ice cream.

A survey made in New York State in which housewives were given a can of commercially canned sliced peaches and a small can (No. 1 tall) of our Julienne

peaches was conducted by a professional survey company for the California Cling Peach Advisory Board. These housewives were accustomed to using sliced canned peaches and were completely unacquainted with the Julienne. The majority preferred the sliced; but a considerable proportion favored the Julienne. The most frequent criticism was that the strips were too thin in cross section; hence, looked too much like shoe-string carrots. We agree with that opinion and consider it a valid objection. Consequently, during the 1950 season as in the 1948 season we used the automatic, commercial size, Urschel fruit and vegetable cutter of the USDA Western Regional Research Laboratory to cut the peaches into strips approximately 3/16 x 3/16 inch in cross section. At the 1950 California Canners League canned fruits sampling the 1949 and 1950 Julienne peaches were sampled by about 400 canners and members of allied industries. Comment was favorable in most cases. Practically all the samplers preferred the strips of larger diameter, that is the 1950 pack. Faculty wives who have used the two packs have also preferred the 1950 product.

A large cafeteria in Berkeley has served the Julienne peaches in various ways: in pies, cobblers, and cottage cheese salad. Customer response was excellent on the salad and cobbler; less so on the pie, probably because peach pie is not a popular restaurant dessert. The manager stated that he would use the product regularly if it were available.

Three bakers stated that the pieces were of satisfactory size for use in pies but that housewives "just don't buy peach pie."

From our experience to date we believe that canned Julienne peaches would be favorably received by many housewives if given a reasonable amount of sales promotion and that restaurants, cafeterias, and hotels would also respond favorably. Like the other new products mentioned in this article the Julienne peaches would not compete directly with the present styles of canned peaches.

As there is no federal standard of identity for Julienne peaches it is probable that any canner who might wish to pack them commercially would have to arrange for a Federal hearing and formulation of such a standard before they could be marketed.

### PEACH SAUCE (SWEETENED PUREE)

Canned apple sauce is now an important pack, amounting to 6,530,000 cases in 1946, 3,500,000 in 1948, and 6,500,000 in 1950. Cranberry sauce has ranged from 1,570,000 cases in 1945 to 6,350,000 in 1947. At present no cling peach sauce is canned. We have found that a tasty product of attractive appearance can be made by the usual apple sauce technique. The peaches are mechanically pitted, lye-peeled, washed free of lye; sliced or chopped; steamed until well cooked; pulped in a tomato pulper with coarse screen; sugar is added to give total soluble solids of 18-20%; well mixed; heated to 93.3° C. (200° F.) or above; canned scalding hot; sealed; and given a long thorough cooling, 20 minutes or more, in water. Cooling is extremely slow owing to the heavy consistency. The sauce is a satisfactory breakfast dish and can also be used in puddings, ice cream, whips, milk shakes, open-face pies, etc. *(8)*.

### CANNED PEACH PUREE AND ICE CREAM BASE

We have for many years packed fruit purees experimentally; and some apricot puree, usually unsweetened, is canned commercially. In our experiments the procedure outlined for peach sauce was used. In some cases sugar was added; in others the product was canned unsweetened. A somewhat finer sieve or screen is used in the pulper than for sauce, as a smooth rather than grainy consistency seems to be preferred.

In some experiments a thickener, gelatin or pectin, was added to give a product suitable for use in the home in making peach ice cream and water ices. This puree is sweetened to about 30% soluble solids before canning.

For puree and sauce the canning cling was found superior to the freestone as the latter used in our tests gave rather soupy products.

### CRUSHED PEACHES

Canned crushed pineapple is a popular product and is well known to most American families. The canning cling peach because of its very firm texture stands up well when canned in a form similar to that of crushed pineapple. A number of years ago J. H. Irish and one of us (W. V. C.) canned about 1500 cases of such a product in a local cannery which sold it under its Choice Grade label in cities in the San Francisco Bay area. Where demonstrators were used housewife response was good. Repeat orders were the rule.

The preferred procedure is about as follows: pitted, halved, lye-peeled clings are coarsely ground into pieces about ⅛ to ⅜ inch in diameter; sugar at the rate of 1 pound to 7 of fruit is added and mixed; the mixture is heated to boiling until the fruit is tender; it is canned at 88-96° C. (190-205° F.); sealed; and cooled thoroughly in cold water, 20 minutes cooling being required usually as heat transfer is very slow. The preferred soluble solids content as determined by refractive index was about 20 to 22 %.

The product is useful in puddings, in making ice cream, or for serving with breakfast cereals or as a dessert, and in various other ways in which crushed pineapple is used *(1, 3, 4, 5)*.

### PIE FRUIT FOR HOME USE

At present fruit for pie making is packed only in No. 10 cans for the commercial baker and jam maker; the housewife cannot buy a No. 2 or 2½ can of such fruit for making pies, jam, etc. We have packed sliced cling peaches in No. 2 cans in a syrup thickened with starch. On opening the can the contents can be used to fill a pie, no additional thickening or flavoring being needed. Also in other experiments the sliced peaches were packed solid pack without syrup by steaming, packing scalding hot in No. 2 cans, sealing, processing at 100° C. (212° F.) until tender and cooling thoroughly. Second quality fruit could be used as slicing improves its appearance. Preparation and canning could be in this case automatic with very little hand labor necessary. The housewife would add sugar to suit and use the fruit in various ways, but particularly in pies. Canned sliced apples for home use are now on the market.

### DEHYDRATED CLING PEACHES

Very few cling peaches are now dried as the yellow freestone varieties are preferred by growers and packers for use in that manner. However, during World War II a very satisfactory dehydrated product was developed by E. Mrak, G. Mackinney, and H. J. Phaff of this laboratory, and by R. L. Perry and C. D. Fisher *(11, 12, 13)*. Several thousand tons of the dried product were used by the armed forces. The procedure was about as follows: Halve and pit by machine; lye-peel; wash; place on wooden trays; steam to kill enzymes and tenderize the flesh; cool by blast of air to near room temperature; sulfur in the fumes of burning sulfur about 3 hours; dehydrate in air blast tunnel dehydrator at 44.5-68° C. (120-155° F.) to about 18-20% moisture. In 1942 Cruess *(2)* reported on the drying of unsulfured peaches.

Variations in the procedure are to slice the peaches as for canning and then treat as above or cut in Julienne strips about ¼ x ¼ inch in cross section and treat as above. These two dried products cook quickly and are useful in pies, puddings, etc.; but unless the trays are covered with cheese cloth the dried fruit sticks badly to the wood of the trays.

Unblanched dehydrated clings are extremely tough and require excessively long periods of cooking to make them tender.

**Vacuum-Dried Pieces and Powder.** The Vacu-Dry Corporation of Oakland, California, has cut dried peaches into small pieces and dried them further in its special shelf vacuum driers to less than 1% moisture content. During drying the pieces become somewhat porous and on that account cook almost instantly in hot water. The armed forces is taking a large amount of apples dried in this form. The pieces can be hammer-milled to a powder in a room of very dry atmosphere.

Probably in time the Vacu-Dry "nuggets" and powder will be marketed in the household trade.

**Syrup Treated Dried Peaches.** Candied and glacé fruit is costly and the consumption is limited. The formerly used commercial procedure was slow and laborious. We have found that a dried product suitable for eating out of hand as a candy can be made as follows: Cling peaches or other firm fruit is peeled, pitted or cored, cut in quarters, cooked until tender in a syrup of 40° Brix consisting of 20% corn syrup, 20% sucrose (cane or beet sugar), and 60% water; allowed to stand overnight; syrup brought to 50° Brix by sugar and corn syrup; heated; allowed to stand several hours and then drained and dehydrated to about 20-23% water content.

A quick process consisted in steaming the fruit; placing it in syrup of 60-70° Brix; holding under high vacuum several hours; draining and drying *(4, 5)*.

**Granules.** A granular product of quick cooking quality was prepared as follows. Dehydrated, sulfured cling peaches were ground in a fine-toothed food grinder; two parts by weight of high quality commercial dextrose such as Cerelose was added; mixed well by regrinding the mixture; drying on trays until brittle dry; and coarsely crushing. The granules are not hygroscopic and cook quickly with water. They may be added in dry form to cake mixes, cooky dough, etc.

They may be ground to a powder which can be used in baked products, ice cream, milk shakes, etc.

### BARRELED PEACHES

A number of years ago halved, peeled clingstone peaches were barreled experimentally in dilute $SO_2$ solution by Mrak, Campbell, and Royer *(10)* of this laboratory and shipped to Germany and England where they were made into jam, etc., by commercial packers. Opinion of the users was favorable. It is probably the high shipping cost which preyents extensive use of this product. (See also reference 6.)

### SUMMARY

1. In normal years there is overproduction of cling peaches for commercial canning; hence, in such years much fruit is wasted. This paper reports on studies made to develop uses for such surpluses.

2. A new product, canned Julienne style peaches in medium syrup, appears promising. The peeled, cored peaches are cut by machine into Julienne strips, canned in medium syrup and sterilized. The product is useful in pies, gelatin desserts, puddings, etc. The strips should be about 3/16 x 3/16 inch in cross section.

3. Canned cling peach sauce made in a manner similar to that used for apple sauce is pleasing in appearance, texture and flavor and useful in a number of ways in the home.

4. Sweetened canned peach puree also appears to have possibilities. It is of finer texture than the sauce.

5. Of still coarser texture is canned crushed peaches made by coarsely grinding peeled, pitted cling peaches, cooking with about 1 part of sugar to 7 of fruit and canning. It is used in the home in much the same ways as canned crushed pineapple.

6. Sliced peaches were thickened, sweetened, and canned for use as pie filling.

7. Vacuum-dried peaches in the form of "nuggets" and in powder form are available commercially although their sale has not yet been vigorously promoted to the household trade.

8. A quick process of preparing candied peaches was devised.

9. Peach granules and powder made by combining and drying the ground dried fruit and commercial dextrose sugar or by powdering the granules are useful in certain baked products, puddings, etc. They keep well and are convenient to use.

10. Barreled peaches preserved with $SO_2$ might find some sale in European countries for preparing jams, and similar products.

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# Factors That Affect the Storage Life of Butternut Squashes[a]

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**The results of a three-year study on the storage quality of Butternut squashes are reported. The effects of method of harvest, seed, light, and darkness on the storage life of the squash are discussed.**

The Butternut squash, *Cucurbita moschata*, is one of the newer varieties of squashes grown on a commercial scale in this locality. Its popularity and the acreage devoted to it are increasing rapidly. Since the mature Butternut squashes weigh about two pounds, they are much better suited for use in the average modern home than the mature Blue Hubbards which weigh eight to ten times as much. The home gardener finds Butternut squash, which has a superior flavor, very desirable because it is a prolific producer and because the vines require much less space than those of many other varieties. Also, Butternut squash can be used in the immature stage as a summer squash, and, when mature, as a winter vegetable. Furthermore, this squash is a good source of a number of nutrients essential for an adequate human diet. It is relatively rich in carotene, the precursor of vitamin A, both during the immature and the mature stages. Holmes, Smith, and Lachman *(1)* found 8.5 mg. of carotene present per 100 g. of mature Butternut squash, as compared with 3.4 mg. per 100 g. of Blue Hubbard squash; and Holmes, Spelman, and Wetherbee *(2)* reported that the amount of carotene in Butternut squashes increased during storage. In view of the desirable characteristics and increasing popularity of these squashes, it is unfortunate that the commercial growers and commercial market men consider them "poor keepers" and plan to dispose of all Butternut squashes by the end of December. Accordingly, this study was undertaken to determine the possibility of lengthening the storage life of Butternut squashes.

## EXPERIMENTAL

This study of the storage life of Butternut squashes covered three winter storage seasons and included squashes raised during three successive growing seasons. The squashes for the first year's study were grown at the Waltham Field Station by R. E. Young in his investigations of the effect of genetic and cultural factors on the improvement of the quality of Butternut squash. The squashes used during the second and third year of the study were grown by Dr. O. H. Pearson, Plant Breeder for the Eastern States Farmer's Exchange. All the squashes were grown under cultural conditions generally employed in this locality by commercial vegetable gardeners. At harvest, the first year's squashes were broken from the vines. As a result the stem end of each squash carried a large area of wounded external tissue. During the second and third years, a small piece of the vine on each side of the stem was left attached to the stem which was 4 to 6 inches long. Thus the stem end of the squashes was protected from wounds that might permit infection by black rot or other destructive organisms. The seed from which the third year's squashes were produced was carefully treated to eradicate all seed-borne disease organisms.

The squashes were carried from the field to the laboratory in lettuce cases lined with paper to prevent bruising the squashes during transit. Each year when the Butternut squashes, approximately 200 in all, arrived at the laboratory, they were examined individually, and two identical groups of sixty were selected. The length of the experimental periods was determined by the storage life of the squashes, that is, the rate at which it was necessary to discard the squashes due to spoilage. Consequently, the experimental periods were 63, 90, and 188 days, respectively, for the three storage periods under consideration.

Each year during the experimental period the squashes were stored in a dry, well-ventilated laboratory attic. One group was stored in continuous darkness, and the other was in controlled artificial illumination. The two groups were placed within two feet of each other but separated by a one-half inch light-proof movable partition. To test the effect of light upon the storage life of Butternut squashes, four 20-inch daylight fluorescent bulbs were placed beneath a 46 × 49-inch reflector, and the unit was suspended 24 inches above the squashes. Both groups of squashes were exposed to the same temperature and to the same humidity conditions. During the fall the temperature averaged 21° C. (70° F.). In each winter the temperature dropped to 15.5° C. (60° F.), and in mid-winter it averaged 10° C. (50° F.). As spring approached the temperature rose to 15.5° C. (60° F.), and at the end of the experimental period, the temperature was 21° C. (70° F.). The relative humidity ranged from 50 to 72% but was approximately 60% for the greater portion of the experimental period. The atmospheric temperature and relative humidity surrounding the squashes were continuously recorded with a Friez automatic recording hygrothermograph.

## RESULTS AND DISCUSSION

A summary of the data assembled during the three-year study of factors that affect the storage life of Butternut squashes is reported in Table 1. At the beginning of the storage period for the first year, the average weights of the squashes were 1193 g. for those stored in continuous light and 1191 g. for those stored in darkness. Corresponding initial weights for the squashes used during the second year's storage were 993.5 g. and 996.4 g., respectively, and the weights for the third year were 1058.0 g. and 1060.1 g. The loss in the weight of the squashes kept in darkness during the first year's storage experiment was greater than the loss in weight of the squashes stored in continuous light.

[a] Contribution No. 802, Massachusetts Agricultural Experiment Station.

TABLE 1

Losses of butternut squash during storage

| Length of storage | Storage in light | | Storage in darkness | |
|---|---|---|---|---|
| | Weight loss | Spoilage loss | Weight loss | Spoilage loss |
| First year | % | % | % | % |
| *days* | | | | |
| 0 | 0 | 0 | 0 | 0 |
| 21 | 7.0 | 1.6 | 7.9 | 10.9 |
| 35 | 10.2 | 26.6 | 10.8 | 18.7 |
| 49 | 11.6 | 62.5 | 13.6 | 45.4 |
| 63 | 15.8 | 77.9 | 20.3 | 69.9 |
| Second year | | | | |
| 0 | 0 | 0 | 0 | 0 |
| 13 | 5.0 | 0 | 5.2 | 0 |
| 27 | 8.8 | 0 | 8.1 | 1.7 |
| 41 | 11.7 | 6.7 | 10.2 | 3.3 |
| 55 | 13.5 | 20.3 | 12.3 | 3.3 |
| 70 | 17.4 | 73.3 | 14.5 | 26.3 |
| 90 | 19.8 | 81.7 | 16.7 | 45.0 |
| Third year | | | | |
| 0 | 0 | 0 | 0 | 0 |
| 14 | 5.6 | 1.7 | 5.2 | 0 |
| 28 | 7.7 | 3.3 | 7.6 | 0 |
| 70 | 12.9 | 11.7 | 13.1 | 3.3 |
| 84 | 15.0 | 18.3 | 15.3 | 5.0 |
| 98 | 18.8 | 25.0 | 17.8 | 8.3 |
| 113 | 20.0 | 25.0 | 19.2 | 11.7 |
| 126 | 21.8 | 26.6 | 20.8 | 15.0 |
| 147 | 23.4 | 26.6 | 21.9 | 15.0 |
| 161 | 25.0 | 26.6 | 23.9 | 20.0 |
| 174 | 26.7 | 26.6 | 24.8 | 25.0 |
| 188 | 27.5 | 43.3 | 27.3 | 30.0 |

During the second storage season, which was about 50% longer than the first, the results were reversed; and during the third storage year, which was three times as long as the first storage period, the weight loss of the squashes was the same for those stored in continuous light as for those stored in darkness. Judged by these results, which were obtained from frequent individual observations and weighings of experimental squashes, the continuous presence or absence of light does not materially affect the amount of loss in weight of Butternut squashes during winter storage. Considered on a commercial scale, it is easier and less expensive to store squashes in darkness than under continuous, uniform artificial illumination.

The rate of spoilage was much more rapid during the first storage period than during the second or third periods. As previously noted, the squashes used the first year were broken from the stems, and thus each squash had a large tissue wound at the stem end; whereas, the squashes used the second and third years had no tissue wounds and carried the stems throughout the experimental periods. This observation that Butternut squashes without stems spoiled more rapidly than those protected by stems is not in agreement with the conclusion of Yeager, Richards, Phillips, Levcowich, and Barratt *(3)* who reported that removing the stems decreased the amount of spoilage. It should be noted, however that they used Blue Hubbard squashes, and it is highly improbable that the conditions for infection (the type, number, and virulence of possible invading organisms) would be the same for the Blue Hubbard squashes as for the Butternut squashes used in this study.

The storage life of the squashes used during the third year was much longer than that of the squashes used during the first and second years. As previously stated, the squashes used during the third storage period were (a) grown from seed that had been treated to eradicate seed-borne diseases, and (b) were harvested without removing the stems. Judged by the results obtained here, the commercial squash growers could materially increase the storage life of Butternut squashes if they observed these two precautions and, in addition, always planted the squashes on new land.

The spoilage losses of the Butternut squashes were due to black rot, caused by the fungus *Mycosphaerella citrullina*. In each of the yearly storage periods, the spoilage losses were significantly greater for the squashes stored in continuous light than for those stored in darkness. During the first year's experiment, the spoilage losses were 77.9% for those squashes stored in the light and 69.9% for those stored in darkness. The corresponding values for the second year were 81.7% and 45.0%; for the third year, 43.3% and 30.0%, respectively. In other words, the spoilage losses for the three successive storage periods were 11%, 82%, and 44% greater for the squashes stored in light than for those protected from the light. These results suggest strongly that under commercial conditions spoilage losses will be significantly less for Butternut squashes stored in the conventional unlighted squash houses than for squashes stored in glass greenhouses frequently used for this purpose. This observation that spoilage is more extensive and rapid in squashes stored in light than for those stored in darkness, together with the observation of Holmes, Spelman, and Wetherbee *(2)* that in all instances the amount of reduced ascorbic acid, carotene, and total sugars was larger in squashes stored under artificial illumination than in comparable squashes stored in darkness, indicates that the physiological processes occurring in squashes during winter storage are significantly stimulated by the action of light.

## SUMMARY

A three-year study has been made of some factors that affect the length of the storage life of Butternut squashes. The squashes were stored in a dry, well-ventilated laboratory attic under controlled conditions. Friez automatic recording hygrothermographs made continuous records of the temperature and humidity of the storage areas. The losses due to spoilage were caused by black rot, *Mycosphaerella citrullina*. The shortest storage life occurred in squashes that were broken from the stem when harvested. The storage life of squashes retaining their stems during the storage period was 50% longer, and the storage life of squashes retaining their stems and grown from seed treated to eradicate seed-borne diseases was three times as long as that of the first group. The weight losses were essentially the same for squashes stored in continuous light or in darkness. Each year of the study the spoilage losses were significantly greater for squashes stored in controlled, continuous illumination than for those stored in darkness.

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# Effects of Freezing on Tenderness of Beef from Different Muscles and from Animals of Different Ages[a]

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**Despite efforts to select tender cuts of meat, much too often they prove to be tough. It is the job of research workers and processors to devise methods that will insure obtaining tender roasts and steaks more often. This is a report on a study of the effect of freezing on tenderizing samples of beef that varied widely in tenderness. The variation was due to scattered locations in the carcass and in the ages of the animals used.**

The relationships between the tenderness of nine different muscles in carcasses of cattle that varied widely in age were studied by Hiner and Hankins *(3)*. They reported that for each of the five age groups the samples could be divided into four tenderness groups, ranging from the least tender to the most tender, as follows: (1) neck and foreshank; (2) round; (3) chuck at the third rib and across the humerus bone, across the eighth rib, short loin or club steak and loin end or sirloin steak; and (4) the tenderloin, or psoas muscle. The variation in tenderness of the samples from veal and from 500-pound steer calves was less than that found in more mature animals. As the age of the animals increased, tenderness decreased for each of the nine samples. The difference between similar samples from veal and 500-pound steer calves was not significant, whereas that between veal and cow beef was. The psoas major (tenderloin) muscle was reported to have a shear value of 7.1 pounds and the rhomboideus (a small muscle in the shoulder) 16.3 pounds in a study of 88 different beef muscles, as reported by Ramsbottom, Strandine, and Koonz (4) and Ramsbottom and Strandine *(5)*. The beef muscles in this report were dissected out and then frozen at —34.4° C. (—30° F.). In another study, Hiner and Hankins *(2)* found that beef became more tender with aging at 0.6° to 1.6° C. (33° to 35° F.).

## EXPERIMENTAL PROCEDURE

The samples used in the present study were the pair mates from the study reported earlier *(3)*. They were from 52 animals slaughtered under uniform conditions, the carcasses being chilled and aged at 0.6° to 1.6° C. (33° to 35° F.). These animals varied from 10-week-old veal calves to 12-year-old cows.

At the end of the aging period of 12 to 15 days the nine pairs of samples were removed for study. Effort was made to have each primal cut represented by one or more samples. The samples were removed from the following locations: (1) neck, (2) foreshank, through radius and ulna bone near joint, (3) chuck, through the third rib, (4) across the arm bone or round bone of the chuck, (5) prime rib at eighth rib, (6) at the middle of the short loin, (7) tenderloin, psoas major muscle below the sixth lumbar vertebra, (8) sirloin at the last lumbar and first sacral vertebra and (9) a full slice of round cut 1.5 inches from the cut surface or face of round made by removal of the rump. Each sample was cut 1.5 inches thick and placed in the refrigerator overnight. Each set of nine samples was from the same side of the animal.

As near the fourteenth day after slaughter as possible, one set of nine samples was tested for tenderness, after heating to an internal temperature of 60° C. (140° F.). Tenderness determinations were made with the Warner-Bratzler shearing strength device. At the time this set of samples was being tested the set of pair mates was weighed and placed unwrapped in a —18° C. (0° F.) freezer and frozen in still air. The samples remained in the freezer 24 hours, were then removed, weighed and thawed in still air at 7.2° C. (45° F.) for 24 hours. These samples were then reweighed and tested for tenderness in the same manner as the unfrozen pair mates.

From each heated sample several small cylinders of meat were removed for testing. Each cylinder of meat was one inch in diameter and cut parallel with the muscle fibers. They were taken from the same locations as those from the fresh unfrozen check samples. Likewise, the same number of cylinders of meat were tested, namely Sample No. 1, 5; No. 2, 4; No. 3, 3; No. 4, 5; No. 5, 3; No. 6, 3; No. 7, 3; No. 8, 7; No. 9, 9. The sample of round, No. 9, was partially subdivided for further study, two cylinders of meat being removed from the biceps femoris and semimembranosus muscles and one from the semitendinosus. Each cylinder of meat was sheared three times and the shearings for each sample averaged to give a single value which represented the tenderness of that sample. The difference in average tenderness before and after freezing represented the increase in tenderness or the tenderizing effect due to freezing.

## RESULTS

As shown in Table 1, freezing had less tenderizing effect in general on the neck and foreshank than on the more tender loin, rib, and chuck samples. This was probably due to the more fiber and connective tissue present in the muscles of the neck and foreshank. There was considerable variation among the remaining seven samples, and no one cut was consistently tenderized more than any other. For example, in the different age groups the tenderloin varied from 6.0 to 18.9%, representing a difference of 12.9%. As would be expected, there was also wide variation within the same age groups. The tenderizing effect on the seven samples of the 900-pound steers showed the least variation, which is of considerable significance. The samples from the veal calves were tenderized more by freezing than any of the other five age groups of cattle, whereas those from the mature cows were the least.

Table 1 shows further that the three muscles of the round were tenderized in all instances except for the semitendinosus in veal calves. Again there was considerable variation between muscles of the same age group and between age groups.

To determine whether these differences were of any significance, the tenderness values were tested for significance of differences between means, using the "T" test (1) for each of the five age groups. These results are shown in Table 2. As reported earlier, there was little tenderizing effect due to freezing of foreshank and neck. This was further shown by the statistical analysis, in which it was found that in no age group was the tenderizing effect significant for the foreshank. The neck sample was significant or highly significant in four age groups, but in veal calves it was not.

The other seven samples from the 900-pound steers were tenderized to a very highly significant degree by

[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 20, 1951. The authors wish to give credit to Harry Slofsky for assistance in analyzing the data.

TABLE 1

Tenderizing effect of freezing at —18° C (0° F.) on beef from animals of different ages and sexes

| Items | Cows | | Heifers Barren | | Steers 900 pounds | | Steer Calves 500 pounds | | Veal Calves | |
|---|---|---|---|---|---|---|---|---|---|---|
| Animals, number | 8 | | 8 | | 25 | | 8 | | 3 | |
| Age, months | 67 | | 37 | | 14 | | 8 | | 2.5 | |
| Meat aging period, days | 13.0 | | 13.8 | | 13.4 | | 12.8 | | 13.7 | |
| | Shearing resistance unfrozen | Decrease in shearing resistance [b] | Shearing resistance unfrozen | Decrease in shearing resistance [b] | Shearing resistance unfrozen | Decrease in shearing resistance [b] | Shearing resistance unfrozen | Decrease in shearing resistance [b] | Shearing resistance unfrozen | Decrease in shearing resistance [b] |
| | *lbs.* | % | *lbs.* | % | *lbs.* | % | *lbs.* | % | *lbs.* | % |
| Sample: | | | | | | | | | | |
| Neck | 35.77 | 10.96 | 30.16 | 6.43 | 25.81 | 6.70 | 21.18 | 6.66 | 18.20 | 14.73 |
| Foreshank | 46.73 | 4.64 | 47.54 | 14.62 | 33.05 | 4.54 | 38.08 | 2.10 | 24.56 | 11.03 |
| Chuck | | | | | | | | | | |
| a. 3d rib | 20.43 | 9.99 | 16.01 | 11.18 | 15.96 | 11.72 | 12.70 | 10.63 | 11.41 | 13.76 |
| b. Cross arm | 23.44 | 9.05 | 18.61 | 8.97 | 17.89 | 12.13 | 14.27 | 8.76 | 12.30 | 19.27 |
| Prime rib at 8th | 23.14 | 6.83 | 18.04 | 11.09 | 16.33 | 8.02 | 14.67 | 15.20 | 10.66 | 10.04 |
| Short loin | 24.46 | 12.31 | 19.08 | 16.56 | 15.76 | 7.87 | 15.53 | 13.14 | 12.70 | 18.19 |
| Tenderloin | 14.05 | 9.32 | 10.52 | 18.92 | 11.71 | 10.85 | 9.62 | 6.03 | 7.85 | 14.90 |
| Loin end | 19.77 | 7.94 | 16.19 | 14.64 | 15.73 | 7.88 | 14.41 | 11.87 | 10.36 | 5.60 |
| Round | 29.63 | 9.65 | 22.41 | 11.02 | 20.99 | 8.43 | 16.94 | 12.51 | 12.98 | 21.11 |
| Muscles of round | | | | | | | | | | |
| a. Semimembranosus | 28.90 | 8.34 | 23.10 | 13.72 | 16.85 | 7.36 | 16.65 | 7.63 | 15.28 | 30.96 |
| b. Semitendinosus | 31.42 | 12.13 | 26.04 | 11.21 | 20.64 | 8.58 | 16.60 | 9.40 | 13.17 | —1.52 |
| c. Biceps femoris | 32.49 | 10.56 | 25.97 | 13.13 | 24.05 | 12.77 | 17.36 | 14.00 | 12.46 | 38.52 |

[b] Due to freezing at —18° C. (0° F.).

freezing. In the veal calves, however, only the loin end (sirloin) was significantly tenderized. As indicated in Table 1 for this group the percentage tenderization was relatively high, but the meat was tender initially. There were only three animals and the tenderness values varied considerably. The samples from the other three groups of animals were tenderized to a significant, highly significant or very highly significant degree.

From examination of Table 2 it appears that the tenderizing effect of freezing on the round was of greater statistical significance than in the case of any of the other eight samples.

Statistical analysis of the data on different muscles of the round revealed that in the 900-pound steers the semitendinosus and biceps femoris muscles were tenderized to a very highly significant degree, whereas in the semimembranosus muscle the change was highly significant. Again none of the three muscles in veal calves were tenderized to a significant degree. Also, two of the muscles of the 500-pound steer calves were tenderized significantly and the third was not. The improvement in tenderness was of greater significance in cows than in heifers.

TABLE 2

Significance of difference of means in tenderness due to freezing at —18° C. (0° F.) on beef from animals of different ages and sexes [c]

| Items | Cows | Heifers Barren | Steers 900 pounds | Steer Calves 500 pounds | Veal Calves |
|---|---|---|---|---|---|
| Animals, number | 8 | 8 | 25 | 8 | 3 |
| Age, months | 67 | 37 | 14 | 8 | 2.5 |
| Meat aging period, days | 13.0 | 13.8 | 13.4 | 12.8 | 13.7 |
| Sample: | | | | | |
| Neck | <0.01 | <0.02 | <0.01 | <0.01 | <0.4 |
| Foreshank | <0.3 | <0.2 | <0.3 | <0.9 | <0.2 |
| Chuck | | | | | |
| a. 3d rib | <0.01 | <0.05 | <0.001 | <0.01 | <0.4 |
| b. Cross arm | <0.001 | <0.02 | <0.001 | <0.001 | <0.05 |
| Prime rib at 8th | <0.01 | <0.01 | <0.001 | <0.01 | <0.3 |
| Short loin | <0.05 | <0.05 | <0.001 | <0.01 | <0.2 |
| Tenderloin | <0.01 | <0.001 | <0.001 | <0.05 | <0.3 |
| Loin end | <0.001 | <0.01 | <0.001 | <0.02 | <0.01 |
| Round | <0.001 | <0.001 | <0.001 | <0.001 | <0.1 |
| Muscles of round | | | | | |
| a. Semimembranosus | <0.001 | <0.01 | <0.01 | <0.05 | <0.3 |
| b. Semitendinosus | <0.01 | <0.05 | <0.001 | <0.1 | <0.7 |
| c. Biceps femoris | <0.01 | <0.02 | <0.001 | <0.05 | <0.2 |

[c] A probability of less than .05 denotes significance, a probability of less than .01 denotes highly significant, and a probability of less than .001 denotes very highly significant.

An analysis of variance was also made of the data. As shown in Table 3, the difference between age groups of animals was highly significant, whereas that between age groups of animals was highly significant, whereas that between samples within one age group was not. The interaction effect between cattle and samples also was not significant.

TABLE 3

Analysis of variance of the tenderizing effect due to freezing at —18° C. (0° F.) on beef from animals of different ages and sexes

| Source of Variation | Degrees of freedom | Sum of squares | Mean square |
|---|---|---|---|
| Cattle Class | 4 | 136.4751 | 34.1188 [d] |
| Sample | 11 | 138.8099 | 12.6191 [d] |
| Cattle — Sample Interaction | | 262.4696 | 5.9652 [e] |
| Within Subclasses | 564 | 4,502.5989 | 7.9833 |
| Total | 623 | 5,040.3535 | ..... |

[d] Highly significant.
[e] Insignificant.

## SUMMARY

Nine samples of beef muscle representing the primal cuts of beef were studied to determine what effect freezing at —18° C. (0° F.) in still air had on tenderization. A total of 52 animals were used. The cattle ranged in age from 10-week-old veal calves to 12-year-old cows. The samples were cut in pairs, one being tested fresh, unfrozen after approximately 14 days, and the pair mate frozen at that time. The frozen samples were thawed at 7.2° C. (45° F.) and then tested. Tenderness was measured objectively.

The foreshank and neck samples, the least tender cuts, were tenderized the least by freezing. In no case was the foreshank sample tenderized significantly; the neck was tenderized to a highly significant degree in three cases but not in the other two. The round was tenderized to a very highly significant degree in four of the five groups of animals, the exception being veal calves. The remainder of the samples varied considerably with respect to tenderizing effect.

The remaining seven samples representing the 900-pound steers were tenderized to a very highly significant degree, whereas those from the veal calves were ten-

derized significantly in only one instance, the loin end or sirloin sample.

The three large muscles of the round, semimembranosus, semitendinosus, and biceps femoris, were all tenderized to varying degrees except for the semitendinosus of the veal calves which was slightly less tender after freezing. The muscles of the veal calves were not tenderized significantly; this was also true of the semitendinosus muscles of the 500-pound steer calves. The remainder were all significantly tenderized.

Analysis of variance showed that tenderizing due to freezing was highly significant between age groups but not between samples from the same age group.

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# Food Processing With Ionizing Radiations[a]

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**Research in the last decade has confirmed the possibility that foods and drugs may be sterilized without heat by ionizing radiations. If laboratory sterilization by this means is to be converted to commercial operations, a number of factors must be taken into consideration, some identical with those in heat sterilization and others entirely different.**

**The various factors involved in the processing of foods and drugs by ionizing radiations are discussed. Among these are the type of radiation employed, the specific inactivation doses of radiations, the effects of irradiation on flavor, color, texture, and nutrients, packaging problems, and dimensions (size and depth) of packages. Consideration is likewise given to the question of the adaptability of radiation processes to presently existing production lines, the radiation equipment needed, and the economics involved.**

As a result of research in the last decade, it appears possible that foods and drugs can be sterilized by ionizing radiations, without heat. In this type of sterilization, a number of factors must be considered. Some of these are the same as those encountered in the development of new types of heat sterilization procedures. Others are entirely different, because of the radical difference between sterilization with heat and sterilization with ionizing radiations. This paper is presented to acquaint food and drug processors with the factors that must be studied when ionizing radiations are under consideration for sterilization purposes.

## FACTORS TO BE CONSIDERED

Briefly summarized, these factors are as follows:

1. Type of radiation.
2. Packaging, with particular reference to the size of the package.
3. What dose is needed to destroy the microorganisms in question?
4. What is the effect of ionizing radiations on enzymes?
5. What is the effect of ionizing radiations on flavor, color, texture, and nutrients in foods?
6. What is the effect of storage life on the irradiated products?
7. Can the process be adapted to present production lines or will these necessarily have to be modified?
8. What building costs might be anticipated?
9. What types of equipment are available?
10. The cost of equipment and the cost of operation of the equipment.

## TYPE OF RADIATION

A number of different types of ionizing radiations and radiations causing excitation are available for consideration. These are treated separately.

**Ultraviolet Light.** Ultraviolet light cannot be considered for the sterilization of foods in the final containers, because ultraviolet emanations have but little penetration into matter and accomplish only surface sterilization.

**X-rays.** X-rays have relatively great penetration into matter. However, only 3 to 5% of the primary electron energy goes into the production of X-rays. The remainder of the electron-input energy produces heat in the target. As a result, the sterilization of a No. 2 can of food by X-rays would require approximately 10 to 20 minutes, even with a high beam current. Therefore, X-rays cannot be considered for this purpose.

**Cathode Rays.** Cathode rays are artificially accelerated electrons or beta particles. The efficiency of their production is relatively high, as approximately 75% of the electron beam energy can be utilized. Therefore, sterilization can be achieved in a second or less. Although their penetration into matter is less deep than that of X-rays of corresponding voltage, their penetration range is of sufficient magnitude so that consideration should be given to this type of radiation. The biological and chemical effects of cathode rays on matter are the same as those of X-rays, and in neither case is any induced radioactivity produced except at voltages in excess of 21 million volts.

**Neutrons.** Neutrons are uncharged subatomic particles. They have relatively great penetration into matter and their sterilizing effect is caused by the production of positive ions or charged nucleii (e.g., carbon and hydrogen) when they bombard matter. These charged nucleii ionize and cause destruction of bacteria. However, neutrons do create induced radio-activity, and for this reason their utilization for the sterilization of foods should be considered with a great deal of caution. For instance, sulfur $S^{32}$, when bombarded with

[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 20, 1951.

neutrons, produces $P^{32}$ which has a half-life of 14.30 days. Iron ($Fe^{54}$), when bombarded with neutrons, produces $Fe^{55}$ which has a half-life of 4 years. Furthermore, the production of neutrons is inefficient. According to Pollard *(3)*, for every 100,000 deuterons hitting a target, the yield is only one neutron! Therefore, from the standpoints of efficiency and induced radioactivity production, neutron radiations do not appear feasible for the sterilization of foods.

**Alpha Particles.** Alpha particles are heavy particles consisting of helium nucleii. They destroy bacteria readily but have little penetration into matter. In fact, their penetration can be stopped by a sheet of paper. Hence alpha particles cannot be considered for sterilization of units of packaged foodstuffs.

From all these considerations, it would appear that the only type of radiation having the three characteristics of efficiency, safety, and practicality is cathode ray radiation. It is on this premise that the rest of this discussion is based.

## PACKAGING

The packaging problems that may be encountered in sterilization by cathode rays are, in general, the same as those encountered in heat sterilization, but there are one or two additional problems. The first of these is the size of the container. At present, equipment is available for irradiating cans that do not exceed 8 inches in diameter.

The limiting factor with cathode rays, however, is the penetration. With 3 m.e.v. cathode rays the penetration into material of unit density is 2.56 cm. (one inch) when that material is exposed from two sides to the electron beam. The relationship between the accelerating voltage of the cathode rays and the penetration is presented in Figure 1.

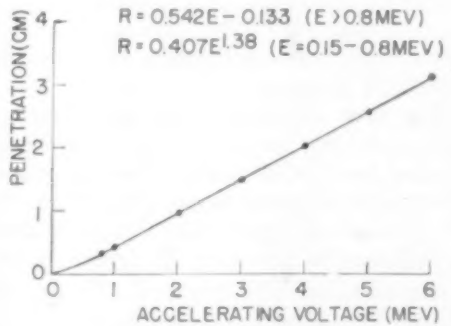


FIG. 1. Relationship between accelerating voltage of cathode rays and penetration.

As the density of a material is a factor in the penetration of the electrons, the amount of penetration being inversely proportional to the density, the container to be selected should be made of material of as low a density as possible and as thin as possible. Aluminum has a density of 2.7 whereas steel has a density of 7 or 8. Hence if cans are to be used to package materials for this type of processing, it would be desirable to fabricate them with aluminum tops and bottoms at least. The penetration of 3 m.e.v. electrons into steel sardine cans is illustrated in Figure 2. The relative amount of voltage or penetration cut off by the can's steel bottom and steel cover is seen to be appreciable.

When 6.0 m.e.v. electrons are used, it is possible to sterilize cans of meat of the size of 12 Z oblong cans (Figure 3).

The penetration of cathode rays into sardine cans is demonstrated visually by the use of methylene blue or resazurin in a manner similar to the use of bentonite and methylene blue in heat processing. The extent of penetration of 2 and 3 m.e.v. cathode rays when directed at the top of sardine cans (16 mm. depth) filled with agar gel containing resazurin dye is illustrated by the two diagrams in the left-hand half of Figure 4. The cross-hatched section represents that portion of the can's contents in which the resazurin dye was not affected by the irradiation, the solid black section that portion where the color of the dye was changed to pink (partial sterilization took place), and the blank section that portion where complete discoloration of the dye (complete sterilization) occurred.

The extent of penetration when sardine cans similarly filled are cross-fired with cathode rays is illustrated by the diagrams in the right-hand half of Figure 4. It will be noted that cross-firing with 3 m.e.v. electrons resulted in complete discoloration of the dye, indicating complete penetration of the electrons into the contents of the can. In the case of the can crossfired with 2 m.e.v. electrons, a layer in the center of the can (from top to

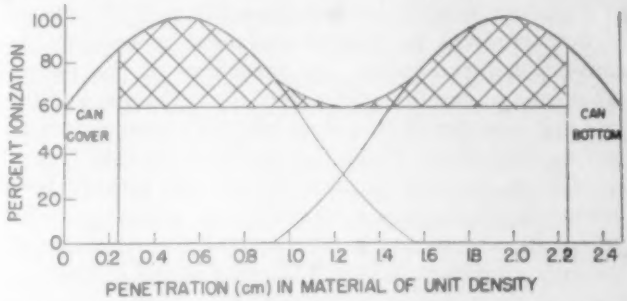


FIG. 2. Ionization in depth in steel sardine cans filled with material of unit density and crossfired by 3 m.e.v. cathode rays.

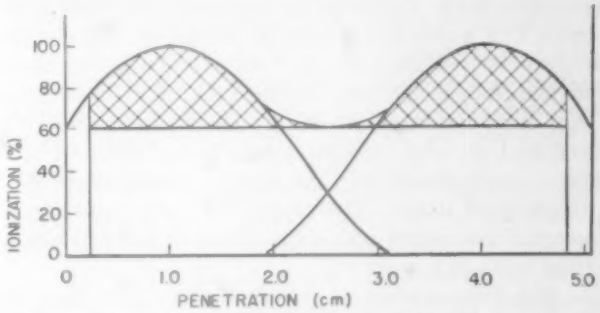


FIG. 3. Ionization in depth in steel 12 Z oblong meat cans filled with material of unit density and crossfired by 6 m.e.v. cathode rays through the shortest dimension.

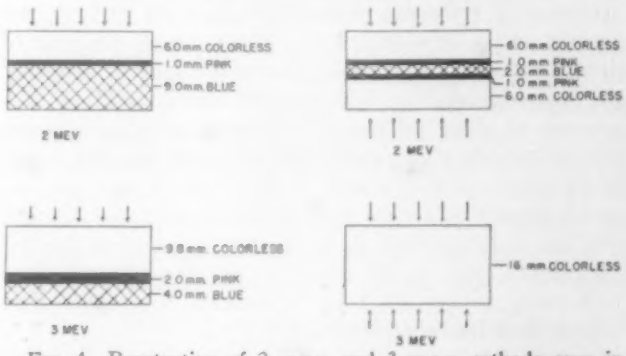


FIG. 4. Penetration of 2 m.e.v. and 3 m.e.v. cathode rays in sardine cans filled with agar gel and resazurin dye. Cross-hatched section represents dye not affected by irradiation; solid black section represents dye changed to pink (partial sterilization); blank section represents complete discoloration of dye (complete sterilization).

bottom) received the minimum dose of cathode rays. When 2 and 3 m.e.v. electrons are used for sterilization purposes, therefore, one should take into consideration not only the conventional packaging requirements but also the limitation of depth of the package (¾ inch).

### LINEAR ACCELERATOR

During the past year, it has been possible to conduct tests on larger-sized containers by using a 16-million volt linear accelerator. As the depth of penetration of cathode rays is dependent on the accelerating voltage, with 16 million volts it has been found possible to sterilize No. 2 cans. This has recently been done with No. 2 cans filled with luncheon meat previously inoculated with spores of P. A. 3679. Further experiments with this equipment on conventional packers' cans are in progress at the Food Technology Laboratories of M. I. T.

### DOSE REQUIRED TO DESTROY MICROORGANISMS

The dose of cathode rays required to destroy the microorganisms in a given food product is ascertained in a manner similar to the determination of the amount of heat required in conventional food processing. In conventional processing, the resistance of the microorganisms in question, the size of the container, and the rate and quantity of heat flow into the container are all factors considered. From the standpoint of cathode ray irradiation, the size of the container has already been discussed. It remains to consider the power units involved in cathode ray irradiation and the resistance of the microorganisms that will be encountered in foods.

### POWER UNITS

Conventionally, heat power is measured in terms of calories or B.t.u. In radiation processes, the most common unit of power is the unit of ionization, namely, the roentgen (r) in the case of X-rays and the roentgen-equivalent-physical (rep) in the case of cathode rays. These units are based on the amount of ionization produced in 1 cc. of air under standard conditions of temperature and pressure. One rep is equivalent to 83.5 ergs per g. of tissue. Therefore, these rep units can be converted into joules and watts, the conventional fundamental units of power.

In the measurement of the dose of cathode rays received by a sample, the electron beam power directed at the sample and the quantity of radiation absorbed by the sample are considered. By measurement of the accelerating voltage and the electron beam current, the amount of power directed at a given sample per unit of time is known. By consideration of the type of material, the type of container, and the size of the container, the amount of absorbed energy or the dose of irradiation can be readily calculated. The type of material being irradiated is of importance in this respect only insofar as its density is concerned, for the higher the density, the less is the penetration of the radiations into the material. This is in contrast to conventional heat processing, where the type of material affects the rate of heat flow into the container.

### RESISTANCE OF MICROORGANISMS

Perhaps the most important single factor in radiation processing is the radiation sensitivity of the particular species of microorganism under consideration. The resistance of a given species of microorganism to ionizing radiations parallels, in general, the resistance of that species to conventional processing. Bacterial spores are the most resistant. The lethal doses of ionizing radiations for various microorganisms are shown in Figure 5.

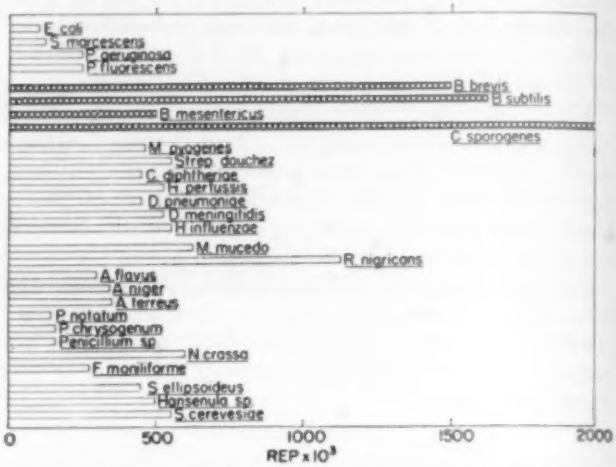


FIG. 5. Doses of cathode rays lethal to bacteria, molds, and yeasts. The bars with circles represent spore-forming bacteria.

Any process which is considered for the sterilization of foods should be able to destroy spores of *Clostridium botulinum*. Unpublished work at the Food Technology Laboratories of M. I. T. has shown that a dose of 2,000,000 roentgens is sufficient to kill spores of *Cl. botulinum* (Type B) in a concentration of 3500 spores per ml.

The destruction of microorganisms by ionizing radiations follows the same pattern as with heat-processing, namely, a first-order reaction. The survival curve is given by the following exponential function:

$$n = n_o e^{-D/D_o}$$

where $n/n_o$ is the survival fraction, D is the dose used, and $D_o$ is the *37%* dose.

The *37%* dose or mean lethal dose deserves some explanation. As the survival curve is exponential and the surviving fraction is constant for any given species of microorganism exposed to any given dose, the sensitivity of a species to a particular type of ionizing radiation is indicated by the dose required to produce one hit per organism or *37%* survival. Hence species of bacteria may be characterized by this means.

It is obvious from this discussion that, as with heat-processing, the dose required to destroy any species of microorganism depends upon the number of that species present. Hence it is necessary to know the maximum number of the most resistant species of microorganism one is likely to encounter in the sample.

With conventional heat processing, the type of pack and the size of the can under investigation control the rate of heat into the "cold spot" of the can. With radiation processing, the type of pack is important from another point of view. Radiations may affect organisms not only by direct hits, as previously mentioned, but also indirectly by the reaction products of radiation in the solvent. These reaction products (free radicals) affect the bacteria present. This is illustrated (see Table 1) by varying the concentration of gelatin in

TABLE 1

Dependence of survival of S. aureus 209 on the protein concentration of the vehicle (fractionated dosage of cathode rays)

| Protein concentration of vehicle (g./ml.) | Fraction of microorganisms surviving cathode ray dose (in rep) | | | |
|---|---|---|---|---|
| | $5 \times 10^5$ | $10 \times 10^5$ | $15 \times 10^5$ | $20 \times 10^5$ |
| 0 | 0.78 | 0.37 | 0.23 | 0.12 |
| $10^{-7}$ | 0.74 | 0.47 | 0.31 | 0.10 |
| $10^{-6}$ | 0.68 | 0.44 | 0.29 | 0.16 |
| $10^{-5}$ | 0.73 | 0.49 | 0.31 | 0.15 |
| $10^{-4}$ | 0.78 | 0.57 | 0.45 | 0.22 |
| $10^{-3}$ | 0.79 | 0.61 | 0.48 | 0.25 |
| Nutrient broth | 0.80 | 0.65 | 0.52 | 0.42 |

suspensions of bacteria and measuring the percentage destructions of the several suspensions at a given dose. Thus it may be seen that the medium in which the microorganisms are to be irradiated may be a factor in determining the correct dose of radiations to be used.

When one is considering the sterilization of a particular food product, therefore, one should obtain a series of simple survival curves of the most resistant species of microorganism likely to be encountered, based on the use of varying quantities of inocula. To obtain these survival curves, samples of a product in the type of container that is to be used are inoculated with different concentrations of a given microorganism. These samples are exposed to different doses of radiation and then tested microbiologically in the usual manner. The swelling of the cans in simple accelerated storage tests or subculturing, as with heat-processing studies, is also performed for sterility evaluation.

## EFFECT ON ENZYMES

The effect of ionizing radiations on enzymes has been studied to a less extent than has the effect on bacteria. However, the studies made have shown that in food materials a great deal more energy (by a factor of as high as 10 or greater) is necessary for complete inactivation of enzymes than for complete destruction of bacteria. This is illustrated in Figure 6, which shows the effect of cathode rays on peroxidase in milk. Here the data indicate that even at a dose of 10,000,000 rep; some peroxidase in the milk was still not inactivated.

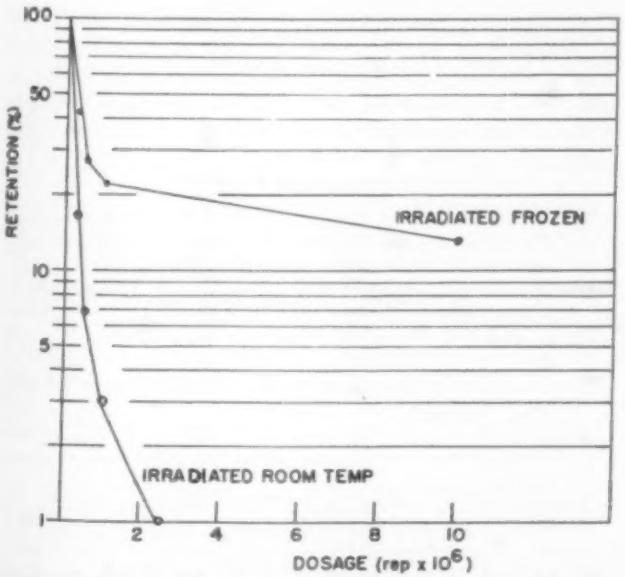


FIG. 6. Effect of 3 m.e.v. cathode rays on milk peroxidase.

It is obvious, therefore, that for economic as well as other reasons it will be desirable to consider some other means of inactivating enzymes in conjunction with the use of ionizing radiations for sterilization. A feasible means may be the rapid heating by electronic energy, such as radar waves, or dielectric heating.

## EFFECTS ON FLAVOR, COLOR, TEXTURE, AND NUTRIENTS

In processing with ionizing radiations as in other types of processing, the effects of the process on flavor, color, texture, and nutrients in foods must be studied. Insofar as nutrients are concerned, studies at M. I. T. *(1, 2, 4, 5, 6)* have shown that in solid foodstuffs vitamins and amino acids are not destroyed by sterilizing doses of ionizing radiations. This is explained by the complex interaction of these compounds with the free radicals produced by the radiations.

The effect of cathode rays on food flavor must be studied with different kinds of food. Off-flavors are produced in certain foods by treatment with sterilizing doses of ionizing radiations. These off-flavors may be obviated by several means, dependent on the food under consideration. Simple freezing and irradiation of the food in the frozen state minimize the off-flavor in milk and orange juice, probably by lowering the diffusion rate of the free radicals produced by the ionizing radiations. The addition of chemical compounds as free radical acceptors may be another means of obtaining the same result, thus avoiding the necessity of freezing. In the consideration of the processing of any food by ionizing radiations, the effect on flavor must be studied and if an off-flavor is produced, means must be taken to avoid this.

The effects of ionizing radiations on color and texture should also be studied. These effects may vary from no effect at all to a noticeable effect. The means of obviating development of off-flavor just mentioned may be equally effective here.

## EFFECT ON STORAGE LIFE OF PRODUCT

The same types of test as used in conventional processing apply in processing with ionizing radiations. Such types include accelerated storage tests, tests to determine the effect of storage on the fat components and the various nutrients, and tests regarding color and flavor.

## ADAPTATION OF PROCESS TO PRESENT PRODUCTION LINES

Adaptation of processing by ionizing radiations to the present-day production lines is dependent largely on the capacity of the available irradiation machines and on the space available for irradiation equipment. Another consideration may be the possibility of sterilizing liquids by continuous flow and aseptic packaging. In previous studies at M. I. T. this has been found possible. Furthermore, cathode rays may be efficiently used to sterilize empty containers, either steel, plastic, or paper.

## TYPES OF EQUIPMENT AVAILABLE AND CHOICE

Several commercial ionizing radiation units for processing materials are available on the market today on an outright sale or on a leasing arrangement. The details of these units are presented in Table 2.

TABLE 2

Types of commercial ionizing radiation units available

| Accelerator | Manufacturer | Volt, m.e.v. | Current, ma. | Power output, kw. |
|---|---|---|---|---|
| Van de Graaff | High Voltage Engineering Corporation | 3 | 4 | 12 |
| Resonant transformer | General Electric Co. | 2 | ca. 4 | 8 |
| Capacitron | Electronized Chemicals Corporation | 2.5 | avg. 1 | 2.5 |
| Transformer rectifier | Philips' Gloeilampen-fabrieken | 2-3 (?) | 4 (?) | ca. 8 |

The Van de Graaff Accelerators that are available have power outputs of 0.5, 2.25, and 12 kw. capacities, operating at voltages of 2, 3, and 3 m.e.v., respectively. The Resonant Transformers have a voltage of 1 m.e.v. as well as 2 m.e.v. When considering the type of equipment that might be purchased today, one should remember that commercial availability is important and should be investigated.

On the assumption that a dose of 2,000,000 rep is necessary for sterilization purposes (this is sufficient for most spore-forming bacteria), we calculate that with a 12 kw. equipment, 2850 lb. of material of unit density could be processed per hour. With an 0.5 kw. equipment, 119 lb. per hour could be processed. Hence in the choice of a piece of equipment, the machine to be selected will depend on the amount of material to be processed. In the case of the destruction of insects in grain, a dose much lower than 2,000,000 rep suffices, namely 25,000 rep. With a 12 kw. machine, 228,000 lb. of grain per hour could be processed.

### Space Available for Irradiation Equipment

Commercial equipment requires preferably a two-story arrangement with the generator on the second floor and the electron window in the lower floor. A basement may be used for housing the generator, with a well dug underneath for the belt on which the food is passed under the beam. A third possibility is having the entire equipment in a well-protected room. However, the protection costs of such an arrangement may be high.

## BUILDING COSTS

Because the effect of ionizing radiations on humans would be equally as deleterious as their effect on microbes, protection from the radiations must be afforded humans. The main type of radiation against which protection is necessary is the secondary X-rays produced when a food is bombarded with cathode rays. In the case of 3 m.e.v. cathode rays, approximately 900 r. of 500 kev. X-rays are produced per $2 \times 10^6$ rep. Hence sufficient concrete should be provided in the exposure room to keep the exposure of humans under the maximum allowable daily dose of 48 milliroentgens per 8-hour day. A typical installation that might be conceived is depicted in Figure 7. The protection costs are minimized by having the electron window (treatment area) in the basement and utilizing the natural protection features of the earth. Because of the necessary protection that must be provided, it is anticipated that building costs may amount to $50,000 per installation.

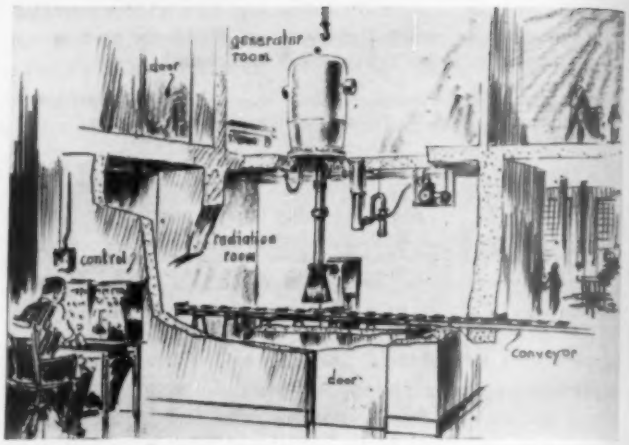


FIG. 7. A typical installation for cathode ray irradiation of foods and food products.

## EQUIPMENT AND OPERATION COSTS

Exact figures as to equipment cost cannot be given at this time. However, the main cost factor to be considered in electronic sterilization is the cost of the initial equipment. Replacements may be necessary for tubes and belts (Van de Graaff), but the cost of such replacements is relatively small. Operational costs are likewise relatively small in comparison with the initial investment.

On amortization over a 5- or 10-year period, the cost per pound of material is small. The cost per operating hour increases with the size of the machine but decreases on the basis of cost per hour per kw.

The typical unit pictured in Figure 7 would consist of two tubes, in case one breaks down, or it would consist of two or three machines, and one machine could be a spare while the others were in use. Each machine would be capable of handling the entire output of a production line, and should a breakdown occur, the line could be switched to the spare machine.

## SUMMARY

The various factors that should be considered in the radiation processing of foods are discussed. The general types of food and food products that have been treated by cathode ray irradiation at the Massachusetts Institute of Technology in the past five years include meats, flours, starches, spices, egg powder, fruit juices, sugars, raw milk, milk powder, amino acids, fish and shellfish, protein hydrolyzates, coffee infusions, vitamins, and molasses.

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# Effect of Processing Procedure on Quality of Frozen Whole-Kernel Sweet Corn[a]

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(Manuscript received April 16, 1951)

**Two types of blanching procedure, blanching on the cob prior to cutting and blanching of cut kernels, have been compared with regard to effect on the quality of frozen whole-kernel sweet corn. Six processing procedures were used on raw material harvested at each of four stages of maturity. Results of chemical analysis and subjective appraisal are presented. Data show that blanching on cob prior to cutting results in higher-quality frozen product and increased yield.**

To produce frozen whole-kernel sweet corn of high quality, it is necessary that the raw material be harvested as near optimum maturity as possible. Further, it is necessary that a minimum of change occur in the product during the interval between harvesting and freezing. Sweetness (reflected in sugar content) is a most important factor in the quality of processed corn. Thus, all measures possible must be taken to minimize losses in sugar as well as other factors that affect quality. These measures include not only prompt handling of raw material to minimize losses due to respiration but also use of procedures that minimize loss of nutrient material between cutting and freezing.

The pericarp of fresh corn is in effect a protective coating around each kernel. As soon as this coating is ruptured its effectiveness is lowered considerably and heavy loss of kernel contents may occur by "bleeding" or "milking." One has only to observe the milky appearance of the water which comes off the face of a corn cutter during the handling of raw corn to realize that loss of soluble and suspended solids can be quite large in this operation. Subsequent fluming, particularly prior to scalding, causes further loss of solids. Thus, any treatment which could decrease the loss of solids in either of these operations would serve to improve the quality of the final processed product.

Bitting *(1)* comments that some processors (in this case canners) contend that heating ear corn causes coagulation of the juices and starches and hence reduces loss of juices and flavor on cutting. Campbell *(2)* points out that there is a difference in opinion among processors as to the desirability of scalding corn on the cob prior to cutting. His data indicate that sugar content of corn scalded on the cob is higher than that of corn scalded after cutting, and he states that quality of the material scalded on the cob was judged to be better, although no appraisal data are presented.

The purpose of the present investigation was to evaluate several processing procedures with regard to their effectiveness in improving the quality of whole-kernel sweet corn. The effect of scalding on the cob prior to cutting was compared with the scalding of the cut kernels. Also, the effect of fluming at various steps in the processing was studied. Golden Cross Bantam was used throughout.

## PROCEDURES

The corn used in these tests was grown by the Utah State Agricultural Experiment Station at Farmington, Utah. Four harvests were made (August 15-24, 1948) with a three-day interval between harvests. The fact that harvest days were equally spaced was accidental, as attempts were made to harvest the raw material at moisture levels as close to certain predetermined values as was possible.

Moisture content was determined on field samples obtained by harvesting the upper ear on every eighteenth plant in each of four rows spaced uniformly throughout the field. For these determinations, the water present was determined by the toluene distillation method on weighed, blender-homogenized samples. The water was collected and measured in Dean-Stark distillation receivers of 25-ml. capacity. When the moisture content of the field sample collected in the early evening approached a desired value, harvest of a certain portion of the field was made on the following day.

Harvest was carried out by picking material from selected rows spaced uniformly throughout the field. Only the upper ear on each plant was taken. To avoid delay between harvest and processing, two pickings were made on each of the days, one in the morning and one in the afternoon. Each harvest lot was processed and packaged separately. The two sets of samples from each harvest day were pooled, thoroughly mixed, and repackaged at the Laboratory in Albany.

The six processing procedures used were as follows: 1, Steam-scalded on the cob, water cooled before cutting. Kernels cut,[c] washed,[d] drained, and frozen. 2, Steam scalded on the cob, water cooled before cutting. Kernels cut, flumed for 2 minutes,[e] washed, drained, and frozen. 3, Kernels scalded in steam, air cooled in moving air stream, washed, drained, and frozen. 4, Kernels scalded in steam, cooled in water, washed, drained, and frozen. 5, Kernels flumed for 2 minutes, scalded in steam, flumed for 2 minutes, washed, drained, and frozen. 6, This procedure has been called the "split-scald." The corn is scalded on the cob for a time necessary to "set the milk" but not inactivate the enzymes. It is then cut from the cob and scalded further to complete enzyme inactivation. In our procedure, the material was scalded on the cob for 1 minute and then cooled in water. Cut kernels were flumed for 2 minutes, scalded in steam for 70 seconds, flumed for 2 minutes, washed, drained, and frozen.

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[a] Presented at the Eleventh Annual Meeting of the IFT, New York, N. Y., June 20, 1951.

[b] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

[c] A commercial corn cutter equipped with rotating knives was used in this process. No difficulty was experienced in handling the material which had been blanched on the cob prior to cutting. The kernels were removed smoothly and easily.

[d] Washing in this step was the same in all six procedures and was accomplished on a shaker-washer equipped with overhead high-pressure spray heads. Chaff, silks, and small particulate matter was removed in this operation. The actual contact time with water was very short, probably of the order of 15-20 seconds, and was the same for all samples.

[e] Since actual flumes were unavailable, the fluming operation was simulated by placing kernels in mesh blanching baskets and agitating gently for the designated time in a large volume of circulating cold water.

In all cases, the temperature of the blancher was 95.5° C. (204° F.). Samples were scalded for a time sufficient to show

by the method of Masure and Campbell *(6)* complete inactivation of peroxidase in the cut kernels. For cob-scalded samples, the time was dependent on maturity of raw material and varied from 3 to 4.5 minutes. The cut kernels were all scalded 70 seconds. The cob-scalded samples were cooled in running water for 5 minutes before cutting. Water cooling of the scalded cut kernels was allowed to continue for 2 minutes. All samples were frozen on mesh trays in an air-blast freezer operating at temperatures between —27.8 and —31.7° C. (—18 and —25° F.).

After freezing, the samples were packaged in No. 2 plain tin cans and hermetically sealed. These were stored at —17.9° C. (0° F.) until all lots of raw material had been processed and were then shipped to the Western Regional Research Laboratory under dry ice refrigeration. Here, they were placed in storage at —23.3° C. (—10° F.). As soon as the pooling, mixing, and repackaging of the morning and afternoon samples, carried out at —23.3° C. (—10° F.), was completed, chemical analysis and appraisal of the samples was begun. Appraisals were made between September 27 and December 13, 1948. Chemical analyses were made between December 1, 1948 and March 29, 1949.

Total solids, alcohol-insoluble solids, and total sugars were determined on all samples, both raw and processed. With raw samples, alcoholic slurries were prepared from uniform lots of the raw material at the time of processing. A known weight of corn was blended with sufficient alcohol to give a final concentration of at least 80%. These were transported to the Laboratory where the analyses were carried out. Similar slurries of the processed samples were prepared at the Laboratory. The methods used for the analysis have been described previously *(5)*.

## RESULTS

The results of the chemical analysis of the raw field samples and of the pooled, frozen samples processed by the various procedures are given in Tables 1 and 2.

The data in Table 1 show a range of about 13.7% in the total solids content of the raw material from the least to the most mature lot used in the preparation of the samples. Since there are no maturity standards available as yet for frozen corn, no positive statement can be made regarding the grades of the frozen samples. However, a comparison of the total solids and refractive index data given in Table 1 with those presented by Krause, Neubert, and Carter *(4)* would classify the material in maturity 1 as "immature," that in maturity 2 as "prime" and that in maturity 3 as "cream" or slightly past prime maturity. Maturity 4 was definitely overmature.

When an examination of the effects of the six processing procedures on the chemical composition of the frozen corn samples is made, the advantages of scalding on the cob prior to the cutting operation are clearly evident. Samples processed in this manner, although flumed after cutting (Process 2), showed highly significant increases in total solids, total sugars and weight per kernel when compared with samples cut and flumed prior to blanching and then flumed again after blanching (Process 5).

Percentage increases of the kernel constituents of the cob-blanched samples when compared to the kernel-blanched samples (Process 2 compared with Process 5) are as follows: Total solids 9 to 33%, total sugars 24 to 89%, weight per kernel 8 to 26%. Other comparisons of Processes (1 and 5, 1 and 6, 2 and 6) show percentage increases of the same order of magnitude in the cob-blanched samples. Thus, blanching on the cob apparently effects changes in the kernel contents, probably by gelation of the starch and proteins, which minimize losses of soluble solids when the cut kernels are in contact with water.

It is not possible to predict whether changes of the same order of magnitude as those reported here would be obtained with other corn varieties or with the same variety grown in different localities. However, it is quite likely that the same trends would be observed. This assumption is supported by the work of Campbell *(2)* and by earlier unpublished data of M. P. Masure and H. Campbell of this laboratory. The latter work, carried out at the Irrigation Experiment Station, Prosser, Washington, during the 1945 season, involved Golden Bantam and Golden Cross Bantam varieties harvested 20 and 25 days after emergence of full silk. A comparison was made of effect of scalding on the cob with scalding of the cut kernels flumed in essentially the same manner as described in this paper. Their data showed advantages in favor of cob-blanching similar to those reported here; namely, the use of these procedures results in a higher yield of frozen product which, on the basis of sugar content, has higher quality than the products prepared by other methods.

## APPRAISAL OF SAMPLES

The frozen samples were prepared [1] for judging by a standardized procedure. Scoring of flavor was done by a panel of 8 to 10 experienced judges. Six samples were tasted at each appraisal period. These were from the same maturity lot processed by the six procedures

[1] One hundred fifty g. of frozen corn were entered in a preheated steamer and the sample was steamed for 8 minutes before serving.

TABLE 1

Chemical analyses raw sweet corn used for preparation of frozen samples

| Maturity | Date of harvest | Time of harvest | Total solids | Alcohol-insoluble solids | Total sugars | Refractive index of expressed juice [f] | Tenderometer reading |
|---|---|---|---|---|---|---|---|
| | | | % | % | % | | |
| 1 | 8/15/48 | Morning | 23.08 | 14.26 | 5.7 | 1.3690 | 82 |
| | | Afternoon | 23.87 | 15.83 | 5.0 | 1.3691 | 80 |
| 2 | 8/18/48 | Morning | 30.70 | 23.24 | 5.0 | 1.3795 | 86 |
| | | Afternoon | 30.97 | 23.93 | 4.0 | 1.3792 | 81 |
| 3 | 8/21/48 | Morning | 34.66 | 27.36 | 3.6 | 1.3862 | 96 |
| | | Afternoon | 33.12 | 25.98 | 3.5 | .... | 93 |
| 4 | 8/24/48 | Morning | 37.29 | 29.99 | 3.2 | .... | .... |
| | | Afternoon | 37.13 | 29.99 | 3.0 | .... | .... |

[f] Obtained with Abbe-type refractometer on juice which had been expressed with the aid of a hydraulic press at a pressure of 500 p.s.i.g. applied for 3 minutes.

TABLE 2

Chemical analyses of frozen sweet corn samples [a]

| Maturity | Processing procedure number [b] | Number of kernels per 100 g. | Total solids, | | Alcohol-insoluble solids, | | Total sugars, | |
|---|---|---|---|---|---|---|---|---|
| | | | % | mg. per kernel | % | mg. per kernel | % | mg. per kernel |
| 1 | 1 | 821 | 22.17 | 27.0 | 15.38 | 18.7 | 4.0 | 4.9 |
| | 2 | 818 | 20.90 | 25.6 | 14.64 | 17.9 | 3.8 | 4.6 |
| | 3 | 920 | 22.16 | 24.1 | 15.15 | 16.5 | 4.2 | 4.6 |
| | 4 | 864 | 21.60 | 25.0 | 15.12 | 17.7 | 3.9 | 4.5 |
| | 5 | 880 | 20.74 | 23.6 | 15.09 | 17.1 | 3.3 | 3.7 |
| | 6 | 866 | 20.46 | 23.6 | 14.97 | 17.3 | 2.9 | 3.4 |
| 2 | 1 | 745 | 28.60 | 38.4 | 22.65 | 30.4 | 2.7 | 3.7 |
| | 2 | 718 | 28.66 | 39.9 | 23.13 | 32.2 | 2.6 | 3.6 |
| | 3 | 926 | 30.52 | 33.0 | 24.78 | 26.7 | 2.4 | 2.6 |
| | 4 | 946 | 28.49 | 30.1 | 23.62 | 25.0 | 1.9 | 2.0 |
| | 5 | 906 | 27.08 | 29.9 | 22.42 | 24.8 | 1.7 | 1.9 |
| | 6 | 930 | 26.17 | 28.1 | 21.49 | 23.2 | 1.8 | 1.9 |
| 3 | 1 | 619 | 32.10 | 51.9 | 25.91 | 41.8 | 2.8 | 4.5 |
| | 2 | 594 | 30.88 | 52.0 | 25.17 | 42.3 | 2.5 | 4.1 |
| | 3 | 729 | 32.47 | 44.5 | 26.66 | 36.6 | 2.3 | 3.1 |
| | 4 | 705 | 31.93 | 45.3 | 26.35 | 37.4 | 2.2 | 3.1 |
| | 5 | 747 | 29.83 | 39.9 | 24.82 | 34.6 | 1.8 | 2.4 |
| | 6 | 708 | 30.20 | 42.7 | 25.26 | 35.7 | 1.8 | 2.5 |
| 4 | 1 | 507 | 34.61 | 68.2 | 28.77 | 56.8 | 2.2 | 4.3 |
| | 2 | 500 | 34.40 | 68.8 | 28.52 | 57.0 | 2.3 | 4.5 |
| | 3 | 594 | 36.07 | 60.7 | 30.27 | 50.8 | 2.1 | 3.5 |
| | 4 | 586 | 35.36 | 60.3 | 29.61 | 50.5 | 2.0 | 3.3 |
| | 5 | 623 | 33.35 | 53.5 | 28.20 | 45.2 | 1.5 | 2.4 |
| | 6 | 610 | 32.09 | 52.6 | 27.79 | 45.5 | 1.5 | 2.5 |

[a] Total solids analyses are averages of at least duplicate analyses of duplicate slurries. Alcohol-insoluble solids and total sugar analyses are averages of single analyses on duplicate slurries. In the case of the total solids the average deviation ranged from 0.03 to 0.37 with 63% of the values less than 0.25, and in the case of the alcohol-insoluble solids was from 0.02 to 0.34 with 85% less than 0.20. The sugar values as reported are accurate to $\pm$ 0.05% or less (as sugar) in 88% of the cases with the maximum average deviation 0.07%.

[b] Described in detail under "Procedures."

as previously described. The sample groups were presented to the panel in a randomized manner.

Each group was judged six times and the replicate mean scores of the judges were analyzed for significance of difference by analysis of variance. The results are given in Table 3.

TABLE 3

Flavor scores [j] of frozen corn samples

| Processing Treatment [k] | Average Flavor Score Harvested at maturities | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Process No. 1 Scalded on cob. Minimum amount of treatment with water | 5.7 | 5.6 | 5.5 | 4.4 |
| Process No. 2 Scalded on cob. Kernels subjected to fluming after cutting | 5.3 | 5.2 | 5.2 | 4.3 |
| Process No. 5 Scalded after cutting. Kernels flumed before and after scalding | 4.6 | 4.0 | 4.1 | 3.0 |
| Process No. 6 "Split scald" | 4.2 | 4.1 | 3.7 | 3.2 |
| Least Difference between scores for significance at P = 0.01 | 0.4 | 0.6 | 0.5 | 0.4 |

[j] Data for Processes 3 and 4 have been omitted for the sake of simplicity in the above table, since it was felt that these processes would have little, if any, commercial application. In all cases the score values were intermediate between those obtained with Processes 2 and 5.

[k] Process numbers refer to the processes described in section on "Procedures."

A highly significant difference is noted between the average flavor scores of the samples scalded on the cob and those which were scalded after cutting. The cob-scalded samples were judged superior in flavor at all maturities. Thus, the advantage of cob scalding over scalding of cut kernels is likewise reflected in the flavor of the resultant frozen product.

Objective color measurements were made on most of the samples with the recording spectrophotometer and the reflectometer. The results are reported in detail elsewhere *(3)*. It suffices to say here that while differences in color of the samples due to maturity were quite apparent, no consistent trends of color change due to processing procedures were noted.

## DISCUSSION AND SUMMARY

The results herein described present a very clear case in favor of scalding corn on the cob prior to cutting. The frozen products prepared by these procedures are superior in flavor quality and contain a considerably higher total solids and total sugar content than samples which were prepared by scalding the kernels after cutting. Also, the former process gives an increased yield of frozen material ranging from 7.2 to 26.1%.

In addition to yielding frozen material of highest quality, the method offers the advantage of simplicity of operation. It is possible to set up a line operation in which fluming can be completely avoided and contact of the kernels (after cutting) with water is reduced to a minimum. The ears, after husking and trimming, can be passed through a blancher (preferably steam). From the blancher, they go directly to the cooler, where cooling is brought about either by a fog spray or by immersion in water.

The cooled ears then pass over an inspection belt where the under-mature and over-mature material is removed. It is a definite advantage to inspect subsequently to blanching, because the color differences with respect to maturity seem to be enhanced by this procedure. The inspected ears then pass on to the cutters. After cutting, the kernels are put through a silker and then over a dewatering device. From there they pass over a final inspection belt and then to a packaging machine and on to the freezer if the plant is equipped for package freezing. If freezing is carried out on a

continuous belt system, the material can be passed from the final inspection belt directly to the freezer.

This procedure is very similar in principle to Process 2, in which the kernels from the cob-scalded material were brought in contact with water for 2 minutes. The analytical and appraisal data showed that this process gives frozen material of high flavor quality in highest yield.

It should be mentioned that Tressler and Evers *(7)* have recognized the advantages previously mentioned in favor of blanching corn on the cob prior to cutting. In addition, they have also noted certain features of the process which they consider to be drawbacks; namely, that (a) large quantities of steam are required for the blanching operation, (b) the size of blanchers must be large enough to accommodate the average corn processing line.

With regard to these points, the cost of the extra steam needed in the process would be offset many times by the increase in value of the pack due to increased yield and quality. In like manner, the increase in the initial investment necessary to install the larger blancher needed for the process would be liquidated within a relatively short time. Thus it is believed that the increase in initial equipment costs and the larger heating capacity needed in the recommended process are justified in terms of the increased yield and quality of the pack.

**Acknowledgments**

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# Notes and Letters

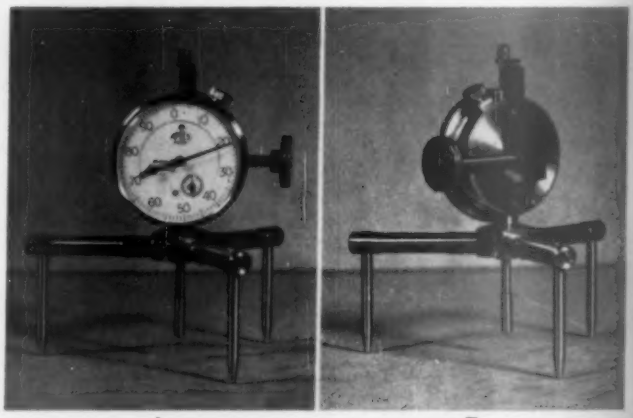
## A New Height Gage for Measuring Egg Quality

The estimation of egg quality frequently involves measuring the height of the yolk and albumen on broken-out eggs. In the past these measurements have been taken with a screw micrometer mounted on a tripod of suitable dimensions. The screw micrometer is slow in operation and difficult to read.

We have recently developed a height measuring gage which uses a direct reading dial indicator. Dial indicators are commonly used for testing the expansion of metals and for other purposes where the plunger operates under spring tension to follow changes in the material upon which it rests. For measuring the height of non-rigid materials it was necessary to remove the spring tension from the plunger and attach a rack and pinion so that the plunger could be raised and lowered manually. The dial indicator so equipped was then mounted on a tripod as shown in Figure 1.

With this device the time required to measure albumen and yolk height on broken-out eggs was reduced by about two-thirds and the ease of taking the readings markedly improved.

The cost of the device including dial indicator was approximately $50.00. Government regulation prohibits the recommendation of one supplier in preference to others. However, the only known manufacturer of these devices is Mr. Robert Rector, 700 Montgomery Avenue, Laurel, Maryland.



A B

Fig. 1. The height measuring gage. A. Front view showing the easily readable dial face. B. Rear view showing the adaptation of the dial indicator so that the plunger is raised and lowered by the rack and pinion.

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Beltsville, Maryland

June 19, 1951.

by the method of Masure and Campbell *(6)* complete inactivation of peroxidase in the cut kernels. For cob-scalded samples, the time was dependent on maturity of raw material and varied from 3 to 4.5 minutes. The cut kernels were all scalded 70 seconds. The cob-scalded samples were cooled in running water for 5 minutes before cutting. Water cooling of the scalded cut kernels was allowed to continue for 2 minutes. All samples were frozen on mesh trays in an air-blast freezer operating at temperatures between —27.8 and —31.7° C. (—18 and —25° F.).

After freezing, the samples were packaged in No. 2 plain tin cans and hermetically sealed. These were stored at —17.9° C. (0° F.) until all lots of raw material had been processed and were then shipped to the Western Regional Research Laboratory under dry ice refrigeration. Here, they were placed in storage at —23.3° C. (—10° F.). As soon as the pooling, mixing, and repackaging of the morning and afternoon samples, carried out at —23.3° C. (—10° F.), was completed, chemical analysis and appraisal of the samples was begun. Appraisals were made between September 27 and December 13, 1948. Chemical analyses were made between December 1, 1948 and March 29, 1949.

Total solids, alcohol-insoluble solids, and total sugars were determined on all samples, both raw and processed. With raw samples, alcoholic slurries were prepared from uniform lots of the raw material at the time of processing. A known weight of corn was blended with sufficient alcohol to give a final concentration of at least 80%. These were transported to the Laboratory where the analyses were carried out. Similar slurries of the processed samples were prepared at the Laboratory. The methods used for the analysis have been described previously *(5)*.

## RESULTS

The results of the chemical analysis of the raw field samples and of the pooled, frozen samples processed by the various procedures are given in Tables 1 and 2.

The data in Table 1 show a range of about 13.7% in the total solids content of the raw material from the least to the most mature lot used in the preparation of the samples. Since there are no maturity standards available as yet for frozen corn, no positive statement can be made regarding the grades of the frozen samples. However, a comparison of the total solids and refractive index data given in Table 1 with those presented by Krause, Neubert, and Carter *(4)* would classify the material in maturity 1 as "immature," that in maturity 2 as "prime" and that in maturity 3 as "cream" or slightly past prime maturity. Maturity 4 was definitely overmature.

When an examination of the effects of the six processing procedures on the chemical composition of the frozen corn samples is made, the advantages of scalding on the cob prior to the cutting operation are clearly evident. Samples processed in this manner, although flumed after cutting (Process 2), showed highly significant increases in total solids, total sugars and weight per kernel when compared with samples cut and flumed prior to blanching and then flumed again after blanching (Process 5).

Percentage increases of the kernel constituents of the cob-blanched samples when compared to the kernel-blanched samples (Process 2 compared with Process 5) are as follows: Total solids 9 to 33%, total sugars 24 to 89%, weight per kernel 8 to 26%. Other comparisons of Processes (1 and 5, 1 and 6, 2 and 6) show percentage increases of the same order of magnitude in the cob-blanched samples. Thus, blanching on the cob apparently effects changes in the kernel contents, probably by gelation of the starch and proteins, which minimize losses of soluble solids when the cut kernels are in contact with water.

It is not possible to predict whether changes of the same order of magnitude as those reported here would be obtained with other corn varieties or with the same variety grown in different localities. However, it is quite likely that the same trends would be observed. This assumption is supported by the work of Campbell *(2)* and by earlier unpublished data of M. P. Masure and H. Campbell of this laboratory. The latter work, carried out at the Irrigation Experiment Station, Prosser, Washington, during the 1945 season, involved Golden Bantam and Golden Cross Bantam varieties harvested 20 and 25 days after emergence of full silk. A comparison was made of effect of scalding on the cob with scalding of the cut kernels flumed in essentially the same manner as described in this paper. Their data showed advantages in favor of cob-blanching similar to those reported here; namely, the use of these procedures results in a higher yield of frozen product which, on the basis of sugar content, has higher quality than the products prepared by other methods.

## APPRAISAL OF SAMPLES

The frozen samples were prepared [1] for judging by a standardized procedure. Scoring of flavor was done by a panel of 8 to 10 experienced judges. Six samples were tasted at each appraisal period. These were from the same maturity lot processed by the six procedures

[1] One hundred fifty g. of frozen corn were entered in a preheated steamer and the sample was steamed for 8 minutes before serving.

TABLE 1

Chemical analyses raw sweet corn used for preparation of frozen samples

| Maturity | Date of harvest | Time of harvest | Total solids | Alcohol-insoluble solids | Total sugars | Refractive index of expressed juice [1] | Tenderometer reading |
|---|---|---|---|---|---|---|---|
| | | | % | % | % | | |
| 1 | 8/15/48 | Morning | 23.08 | 14.26 | 5.7 | 1.3690 | 82 |
| | | Afternoon | 23.87 | 15.83 | 5.0 | 1.3691 | 80 |
| 2 | 8/18/48 | Morning | 30.70 | 23.24 | 5.0 | 1.3795 | 86 |
| | | Afternoon | 30.97 | 23.93 | 4.0 | 1.3792 | 81 |
| 3 | 8/21/48 | Morning | 34.66 | 27.36 | 3.6 | 1.3862 | 96 |
| | | Afternoon | 33.12 | 25.98 | 3.5 | .... | 93 |
| 4 | 8/24/48 | Morning | 37.29 | 29.99 | 3.2 | .... | .... |
| | | Afternoon | 37.13 | 29.99 | 3.0 | .... | .... |

[1] Obtained with Abbe-type refractometer on juice which had been expressed with the aid of a hydraulic press at a pressure of 500 p.s.i.g. applied for 3 minutes.